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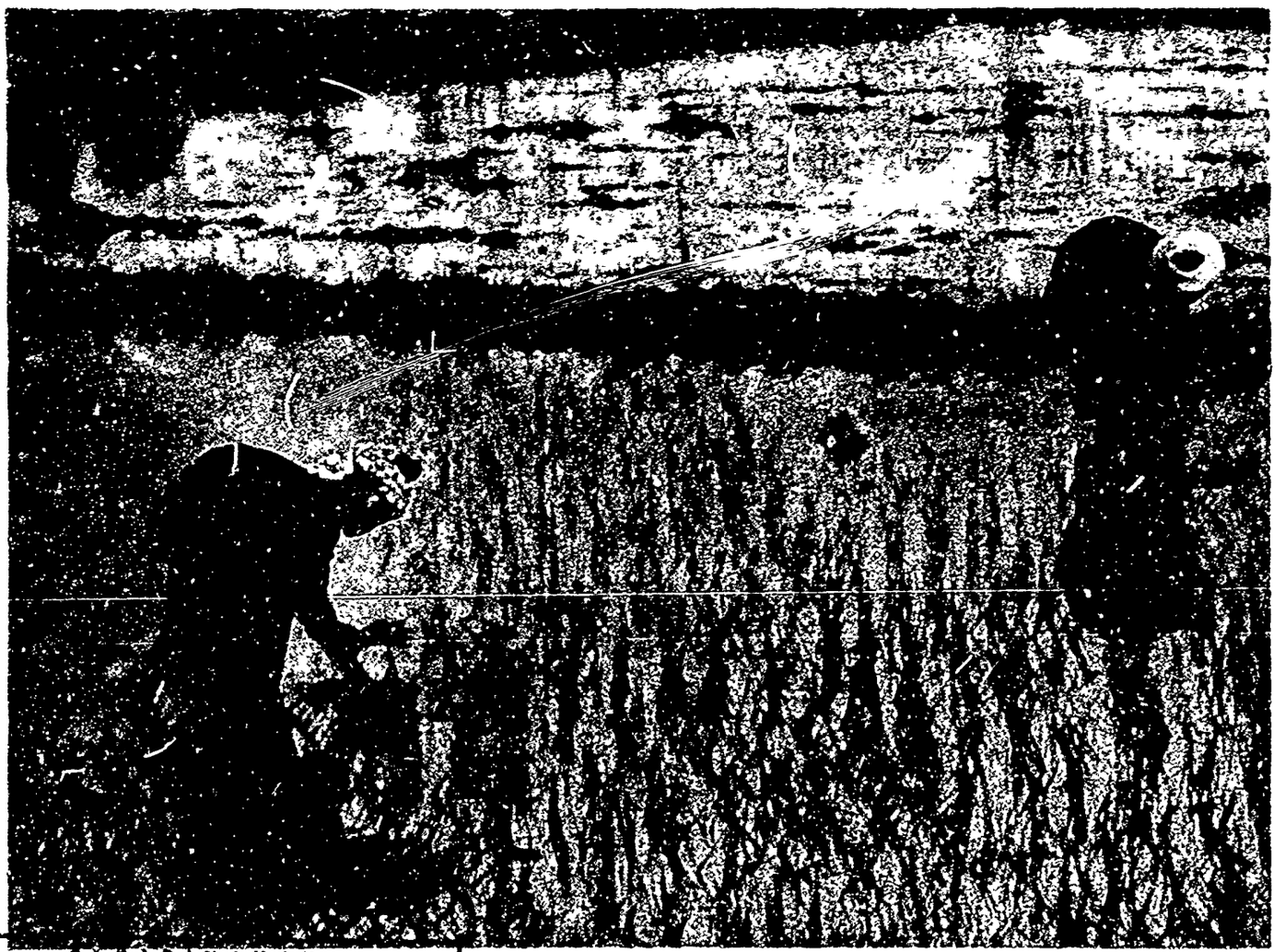
RAINFALL IN BURMA



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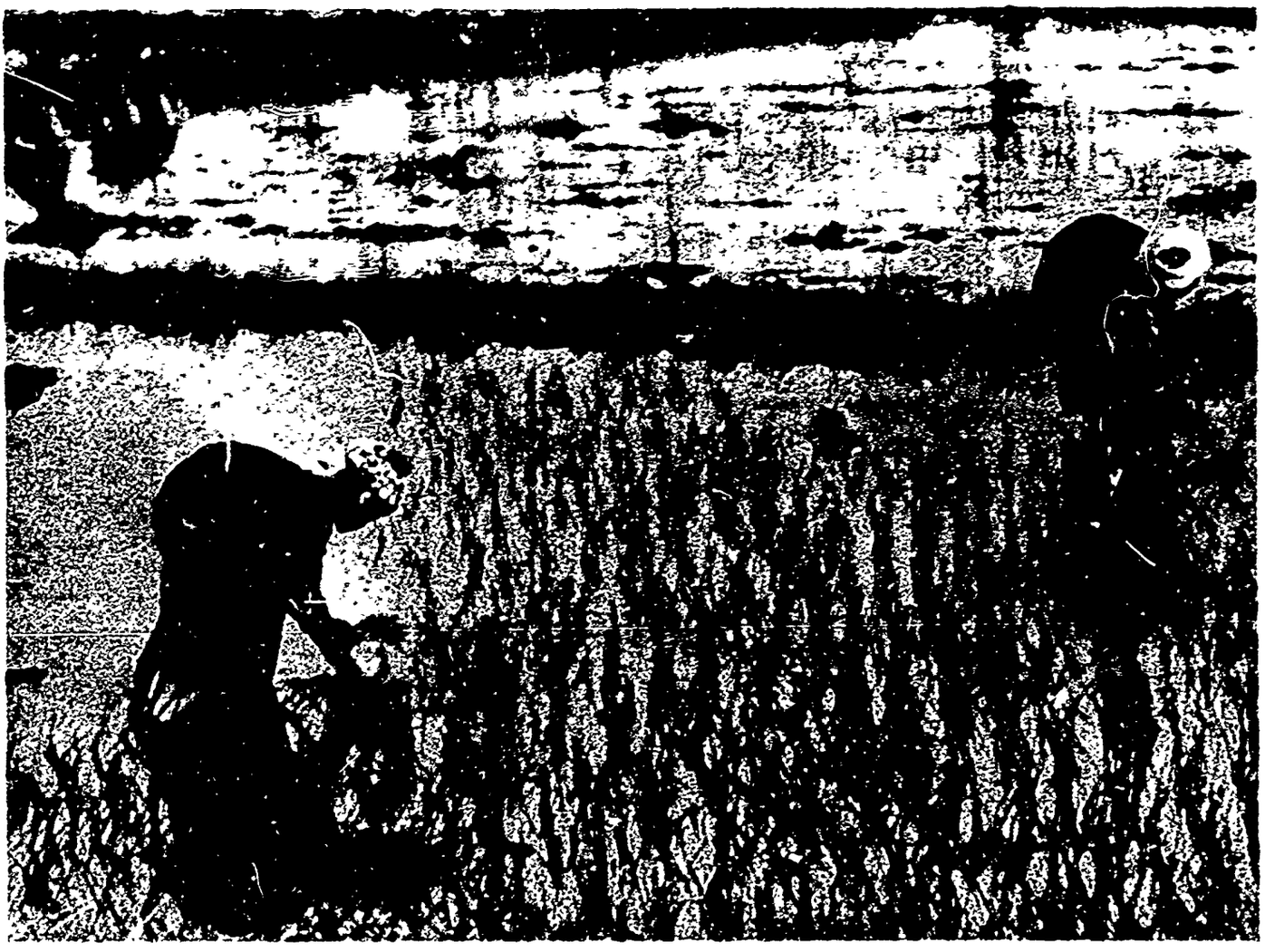

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This study was supported by the U.S. Army Quartermaster Corps Research and Engineering Command, Project No. 7-83-01-008, Contract No. DA 19-129-QM-1966.

Chief Cartographer - Jay Crane

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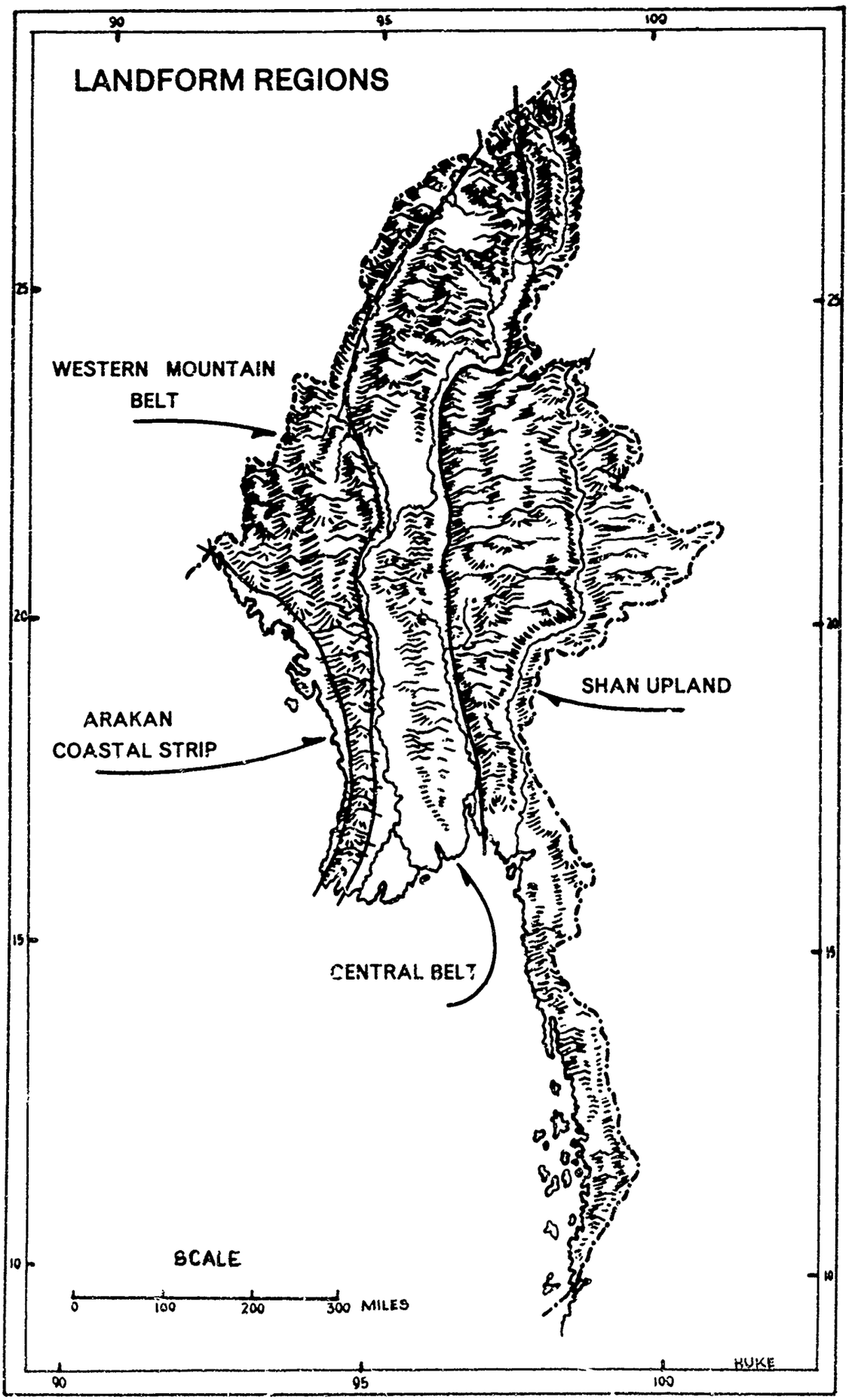
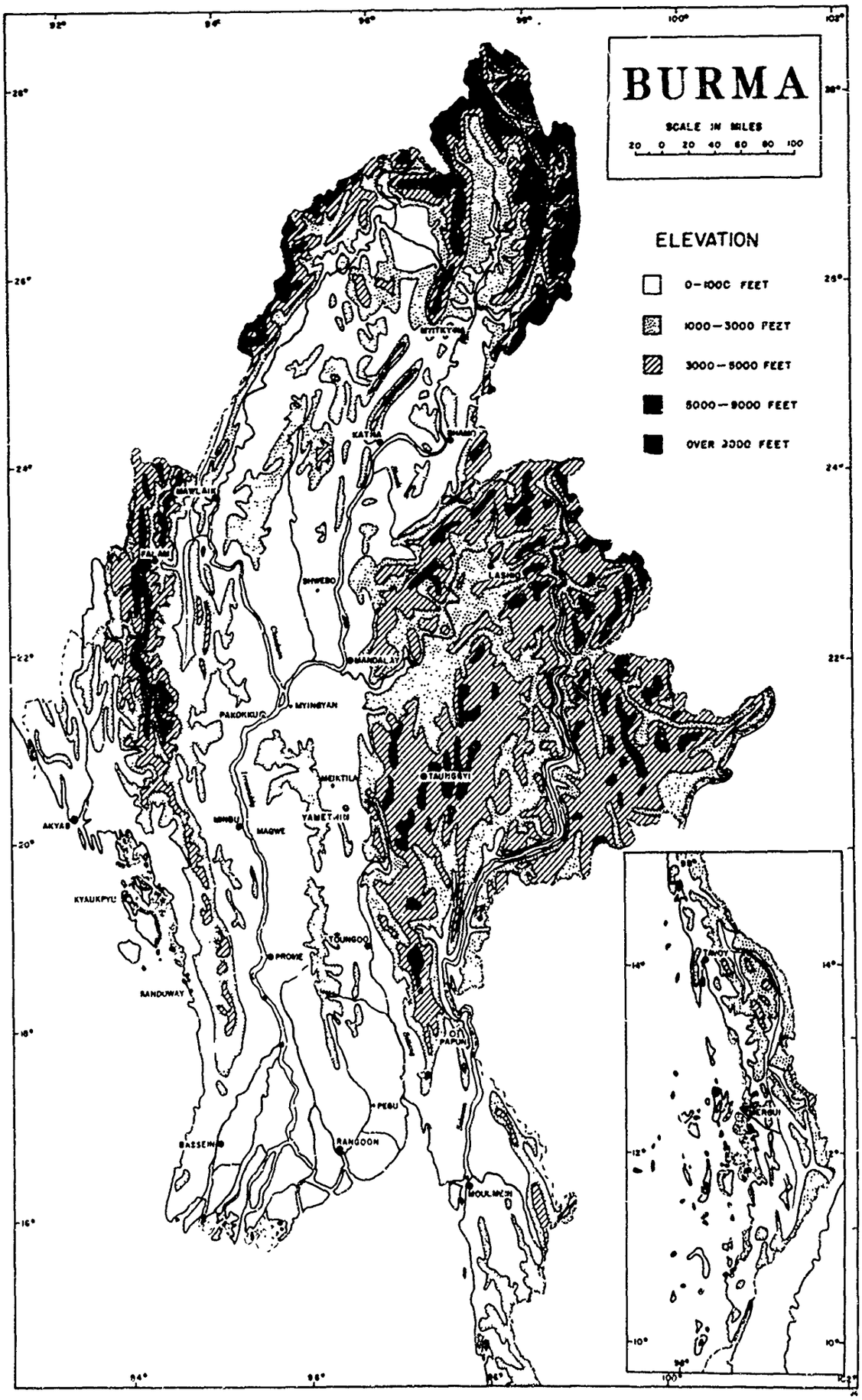
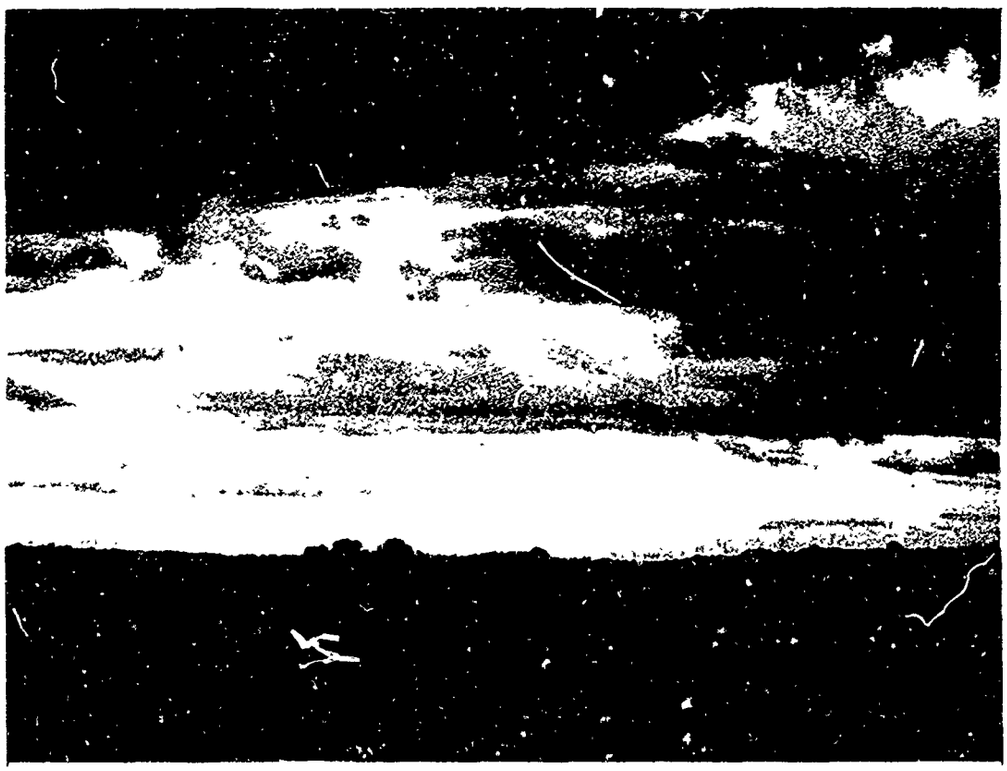

LANDFORM REGIONS
WESTERN MOUNTAIN BELT
ARAKAN COASTAL STRIP
SHAN UPLAND
CENTRAL BELT
SCALE
0 100 200 300 MILES
90
95
100
25
20
15
10
HUKE

MAP 1


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
ELEVATION
0-1000 FEET
1000-3000 FEET
3000-5000 FEET
5000-9000 FEET
OVER 9000 FEET
MYITKYINA
KATHA
SHAMO
MAWLAIK
FALAM
SHWEBO
LASHIO
MANDALAY
MYINGYAN
PAKOKKU
MEIKTILA
TAUNGGYI
YAMETHIN
MINBU
MAGWE
AKYAB
KYAUKPYU
TOUNGOO
PROME
RANDUWAY
PAPUN
PEGU
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

MAP 2

This study was supported by the U.S. Army Quartermaster Corps Research and Engineering Command, Project No. 7-83-01-008, Contract No. DA 19-129-QM-1966.



Of all the elements of the physical environment rainfall is by far the most important to Burma. It is upon the rains of the monsoon season that the farmers of the country depend for the production of the all important rice. In the Irrawaddy Delta, pictured above, the modest rain brought by the early monsoon soaks the fields and heralds the beginning of the agricultural year.

RAINFALL IN BURMA

Of all the elements of the physical environment none is more important than rainfall. In a country such as Burma where 75 percent of the population is engaged in farming and where irrigation is but little developed, life itself depends upon the God-given rains. During half the year the land lies scorched and brown under the cloudless sky. Stubble of the past season's rice crop shares the fields with tiny whirlwinds of dust which dance unchallenged across the horizon. Here and there a water buffalo plods toward a tiny mud hole seeking relief for his parched and cracking hide. As far as the eye can see no human being stirs — for this is the hot season. Men, plants and animals are almost in a state of suspended animation — awaiting the rains.

In May when the first rains arrive, life quickens and once again has a meaning. Trees break out in glorious flower, wild life emerges from hiding as if by magic and the countryside is suddenly alive. Plows, harrows, mattocks and hoes are wielded with a vengeance and the air is filled with song. The monsoon rains have come!

The wonder of the monsoon has long fascinated man. The seasonal reversal of winds has been known in Asia since antiquity — in fact the name monsoon is derived from an Arabic word mausim, or "season". Early traders understood the facts of the monsoon winds and took advantage of the reversal to sail their difficult to handle dhows from Southern Arabia to East Africa and back, one round trip being accomplished each year.

The same winds are recognized today by the farmers of Burma and it is around the resulting alternation of wet and dry periods that agriculture, and thus life itself, revolves. The facts of the monsoon reversal may be well-known, but the ultimate causes are only now beginning to be understood.

A usual but vastly oversimplified and perhaps even incorrect explanation of weather and climate in South and Southeast Asia depends almost entirely upon the concept of differential heating of land and water. According to this theory the broad land mass at the latitude of the Tropic of Cancer becomes overheated in the summer months. The heated air rises and causes a general surface flow of air from the Indian Ocean in a northeasterly direction onto the land. Air is cooled by a variety of mechanisms including orographic uplift or squeeze, frontal action and convectional activity. Cooling of these moist air masses brings the monsoon rains.

During the low sun period excessive cooling of the land mass results in the development of a high pressure center and the resultant flow of air from land to sea in a normal trade wind pattern. At this season the weather is clear and rainfall is the exception. 1.

As more data is collected and more research is done climatologists and meteorologists are more and more receptive to the idea of the Jet Streams as a major control of the monsoon system over South and Southeast Asia. According to this theory the Subtropical Jet Stream is subject to violent fluctuations from season to season. During the "winter" this high altitude air stream flows at a location approximately over the south slope of the main Himalaya Ranges. These rivers like flows of air move at speeds of 100 to 300 MPH and at elevations of 18,000 to 40,000 feet. Coriolis force tends to "spin off" air from these flows and to pile it up to the right hand side of the path of air flow. Thus high pressure ridges, extending all the way to the surface, develop to the south of the Jet Stream. This high pressure causes a surface flow from land to water, from India-Pakistan-Burma toward the Indian Ocean, and results in dry weather.

During summer months the Subtropical Jet Stream moves abruptly to the north side of the Tibetan Plateau. Flow of air from the high pressure ridge is blocked by the massive mountain ranges. A surface low develops at the heat equator and the inter-tropical front moves to locations over India; thus the surface flow of air is from the Arabian Sea-Bay of Bengal to the India-Parkistan-Burma land mass, a reversal of "winter" conditions. These "summer" conditions are ideal for producing heavy precipitation.

No matter which explanation is accepted the resultant climatic pattern is similar. Burma lies in an area subject to a rainfall pattern well-known to almost

---

1 For an example of this explanation used in a major text see: George B. Cressey, **Asia's Lands and Peoples**, McGraw Hill 1963, pp 24-28

everyone. The monsoon climate involves five or six months of very heavy rainfall followed by six or seven months of very dry conditions. This rainfall pattern is the subject of investigation in the present paper.

During the wet season over the hilly and mountainous eastern uplands 70 percent cloud cover, such as is pictured here over Taunggyi, is the rule. Rainfall comes in a series of showers, some light and some heavy.

LANDFORMS AND RAINFALL

The surface features of Burma bear a very important relationship to the rainfall pattern. In certain areas the main alignment of mountain ranges lies directly athwart the path of the prevailing wind and thus produces considerable adiabatic cooling and very heavy precipitation on the windward slopes with marked rain shadow effects on the lee slopes. In other areas the convergence of mountain chains produces an orographic squeeze effect and this in turn induces heavier than expected rainfall.

The surface features of Burma appear to be relatively simple and may easily be divided into four north-south belts each of which is significant to an understanding of the rainfall patterns. This simplicity of landform patterns exists despite an extremely complex underlying rock structure and a very involved geologic history. Basically the country may be likened to the shape of a kite with mountain and upland regions comprising the four sides of the diamond and the long tail. The central portion of Burma consists of an extensive lowland area while more limited lowlands are nestled between the mountains and the Bay of Bengal and the Andaman Sea.

A. The Shan Upland

The Shan upland is a deeply dissected plateau underlain by Archean, Palaeozoic and Mesozoic rocks. The area is, geographically, the oldest portion of present day Burma. The upland averages roughly 3600 feet in height and its western edge is clearly marked off from the central lowland by a well-defined north-south fault scarp which often rises 2000 feet in a single step and which acts to produce

The Shan Upland is characterized by a strong north-south orientation of ridges and valleys as shown by this view a few miles east of the town of Taunggyi.

orographic cooling of air and a marked increase of rainfall. This escarpment bounds the eastern side of the Dry Belt in one of the most striking and most stable climate boundaries in the country.

Much of the surface of the Shan Upland is of a steeply rolling hilly nature, in many respects similar to the surface of the New England Upland. In many places, but most commonly in the northern and eastern portions of the upland, the surface is rough and rugged reaching heights of 6500 feet.

Great blocks of massive limestone, sandstone, metamorphic rocks and granites are found in highly folded complexes with a very strong north-south tendency. This pattern gives a great variety of landscapes with the north-south alignment of hills and valleys the chief unifying characteristic. As the careful observer moves from place to place in the Shan Upland he is struck by the vegetation and land use differences between the rolling upland and the more sheltered vailey bottoms. In part this change may be due to temperature differences and in part to soil differences. Such differences do not show on even the best maps of the area for the valleys are only a mile or two wide and the rainfall records for the entire Shan Upland are based on only 12 rain recording gauges of which four are full-time reporting weather stations. Clearly such scanty data are insufficient for detailed analysis.

Even though the upland is topographically old many of the larger rivers, notably the Salween and the Myitnge, an important tributary of the Irrawaddy, show youthful characteristics. During much of their traverse of the upland they are deeply entrenched and have numerous falls and rapids. Other smaller rivers such as the Pilu have developed courses in areas of plateau limestone and flow sluggishly through broad valleys. On higher ground to either side of such valleys polje are common.

The Shan Upland merges gradually with the Putao Knot to the north and extends well into Thailand on the east. To the south, especially in Tenasserim, the plateau character of the landscape is lost and is replaced by long bands of parallel hills and low mountains with narrow valleys between. Elevations here average 2800 feet with a number of individual ridges rising to 5000 feet. The hill and valley alignment in Tenasserim is nearly parallel to the coast and cuts almost directly across the path of the summer monsoon winds. The alignment is well illustrated by the course of the Tenasserim River which originates northeast of Tavoy and flows southward within 20 to 50 miles of the sea for over 150 miles before breaking through the hills south of Mergui.

The orientation and location of this southern extension of the Shan Upland helps to produce some of the heaviest rainfall in all of Burma. The equatorial location also helps assure this coast the longest rainy season in the country.

B. The Central Belt of Burma

The Central Belt, in contrast to the Shan Upland, is a relatively young section of the country. This region was occupied, as recently as the latter part of the Tertiary period, by a great arm of the sea known as the Gulf of Burma. Great depths of sediments were deposited and were later consolidated into sandstones and shales. This broad Central Belt extending from south of the Putao Knot all the way to the present day Gulf of Martaban was uplifted and was then subjected to degradation by the Proto-Irrawaddy and the Proto-Chindwin Rivers. The softer rocks yielded readily and broad valleys were created. As sea levels rose once again the streams agraded their channels and deep alluvial deposits were laid down.

The harder rocks of the Central Belt resisted erosion by the giant ancestors of the present Irrawaddy, Chindwin and Sittang Rivers. It is these more resistant rocks that today stand as isolated ranges of hills buried knee deep in seas of alluvial deposits. Thus the Pegu Yoma separate the Irrawaddy Valley from that of the Sittang and in part help to create the Dry Belt of Central Burma. The southern-most spur of the Pegu Yoma supports the magnificent Shwe Dagon Pagoda at Rangoon. From this point north the range gradually increases in height and breadth to culminate at Mt Popa, south of Pakokku, where a single peak reaches 4981 feet. This range receives significantly higher precipitation than do the plains to the east and west North of Mt. Popa, where the Pegu Yoma end, the rainfall totals fall off abruptly and the Dry Belt achieves its greatest permanence

North of Shwebo and Katha other ranges of hills, similar in origin to the

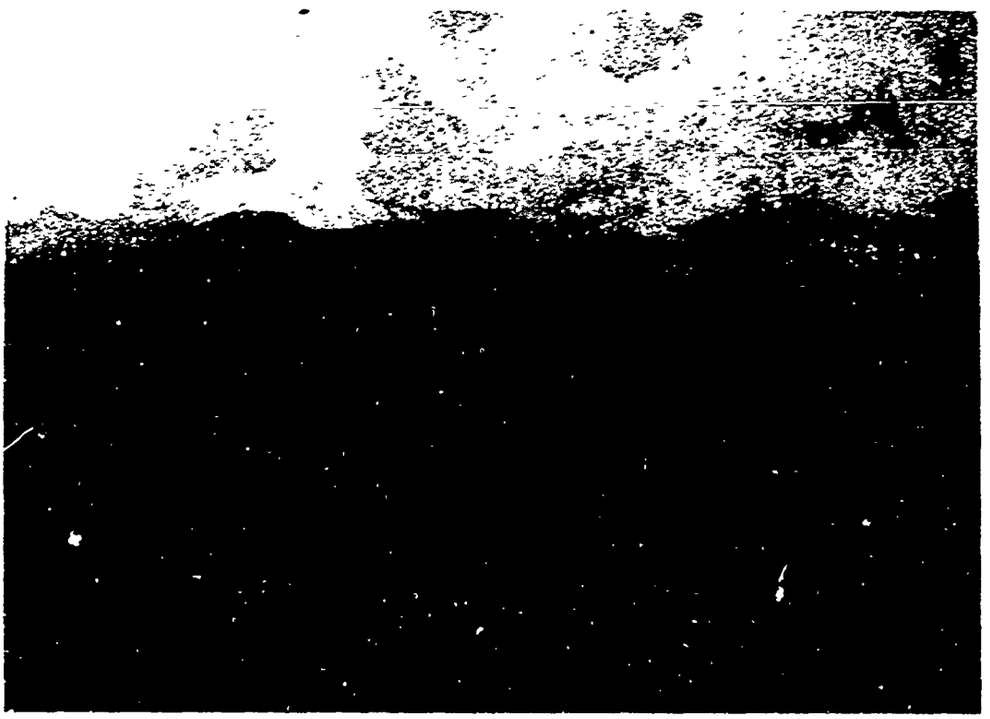
Pegu Yoma, make their appearance above the alluvium. These ranges become wider and higher further to the north and, in fact, are the foothills south of the Putao Knot. To the west these hill ranges merge with the Western Mountain Belt.

Air masses moving north across the Central Belt are confined by the higher mountains to both east and west and are forced up and over the Shwebo, Katha and other hill ranges. Orographic cooling increases the rainfall on these areas and thus the hills, in effect, mark the northern limit of the Dry Belt.

C. The Western Mountain Belt

The Western Mountain Belt is composed of several parallel ranges that originate from the Putao Knot and extend all the way to Cape Negrais at the southwestern corner of the Irrawaddy Delta. This mountain system is broadest and highest to the north and gradually diminishes in stature toward the south. Through the Chin Special Division along the Indian border elevations of a number of ridges reach 9000 feet while the highest peak, Mt. Saremetti on the Assam border, reaches an elevation of 12,551 feet. Along the Arakan Coast the crest of the range averages roughly 5000 feet with a number of gaps at 2500-3500 feet.

From a climatological point of view the portions of the Arakan Yoma paralleling the coast from the Pakistan border to the Irrawaddy Delta are of particular importance. Here the summer monsoon winds from the warm bay of Bengal meet the hills at right angles. As the air is forced over the hills, cooling takes place and the heaviest rainfall in Burma is recorded. Where the mountains are higher, as behind Akyab, the rainfall is most intense while further to the south where the relief is lower precipitation too is more modest.



In the far northeastern corner of Burma hills and mountains to the east of the Irrawaddy rise to heights of 9,000 feet along the China border. During the rainy season only the lower 1,500 feet are visible below the solid cloud cover.

To the lee of these ranges the effect is equally apparent. A rain shadow is well-developed from Prome to the Central Chindwin Valley and is most strongly developed between Minbu and Pakokku. Air descending the eastern slopes of the Arakan Yoma is warmed adiabatically and little precipitation falls in the area.

The Western Mountain Belt swings in a broad arc and toward its northern end the trend of the ranges is from southwest to northeast. At the northern tip of Burma these ranges join forces with the northern end of the Shan Upland to culminate in the Putao Knot. This mass of mountainous terrain is high, rugged and, in part, unexplored. Several peaks both along the Assam border and the China border reach heights of well over 12,000 feet. At the extreme northern tip of Burma Hkakabo Razi reaches 19,296 feet above sea level.

Ranges of this height converging at the northern end of a long lowland funnel through which summer monsoon winds naturally focus provide a topographic trap. As air masses are caught in this gigantic box canyon orographic squeeze becomes well-developed. The funnel becomes more and more narrow as air moves further to the north. This, combined with the fact that ground surface becomes increasingly rugged, induces expansion aloft, rapid air cooling massive cloud development and heavy rainfall. Thus rapid increases in average annual precipitation are experienced as one travels from Thamo to Myitkyina and further north along the Irrawaddy Valley.

D. The Arakan Coastal Strip

The Arakan Coastal Strip is a narrow belt between the Arakan Yoma on the east and the Bay of Bengal on the west. In the northern portion of the belt there is a broad area of level land formed by the flood plains of the several streams which debauch from the hills and mountains to the north and east. To the south the coastal strip is considerably narrower and is in fact displaced altogether in several places where the Yoma reach the Bay.

The Arakan Coastal Strip is of roughly the same age as the Central Belt and was formed in a like manner. This is by far the smallest of the geomorphic regions of Burma and from the climatological point of view is the least significant.

GATHERING RAINFALL DATA

Rainfall data in Burma are collected from a network of 228 raingauge stations distributed throughout the country as shown on map 3. A count of the stations shown on map 3 will reveal that 14 of the stations have been omitted. This is so because at several of the District capitals two raingauge stations are located within a mile of each other, too close to be distinguished on a map of the scale presented. Where two stations were found to be in close proximity the data from the station of longest record was used in this report. For example, a few miles north of Rangoon data were available from Mingaladon Airport, a meteorological observatory, and from Mingaladon Golf Club, a privately operated station. In this case the airport data was used and the golf club data ignored.

The rainfall data are collected by three different government agencies of which the Meteorological Department is by far the most important. This Department operates 30 full-time permanent observations scattered widely throughout the nation and located mainly at the District and State capitals. In addition there are 12 other observatories fully equipped to measure rainfall, temperature, humidity, pressure and wind. These 12 are also located in District capitals and differ from the 30 above only in that they are classed as non-permanent despite the long records compiled.

The Meteorological Department also maintains equipment and pays part-time observers at 150 raingauge stations. These observers record the data from their 8 inch raingauge each day at 0930 local time and forward the results periodically to the central office in Rangoon. These gauges were discovered to be located in fenced enclosures with adequate exposures on sites chosen by the Meteorological Department. Where the reports are available these data are considered reliable.

The Irrigation Department also maintains a system of gauges centered in the Dry Belt of Central Burma. These 29 stations are equipped with 8 inch gauges and are cared for by full-time observers. The gauge at Meiktila is considered one of the best in the whole country and is of the automatic tipping bucket variety.

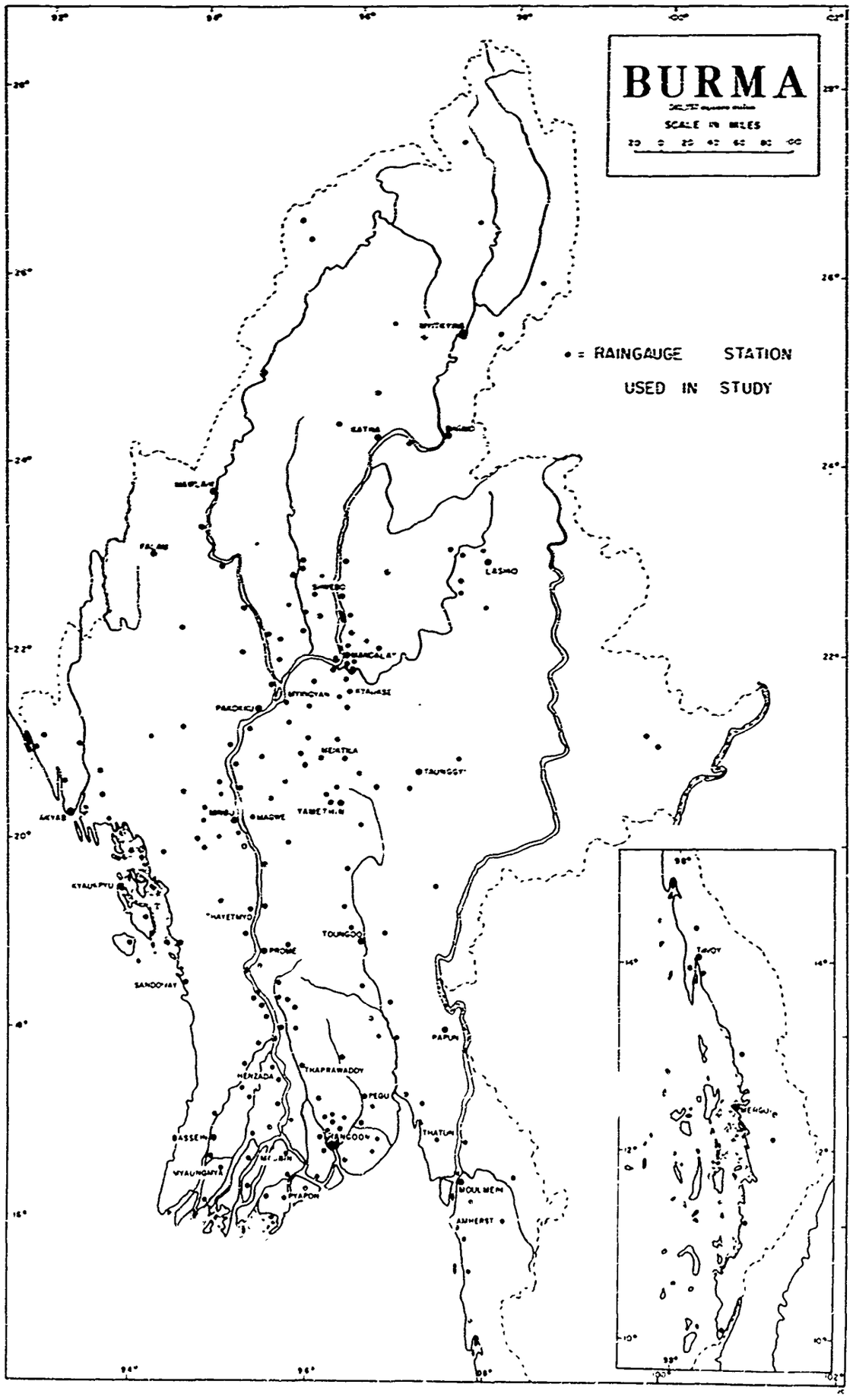
The Agricultural Department, too, helps in the collection of rainfall data. This Department maintains a system of experimental farms and at seven of these, 8 inch rainfall gauges are operated by competent men with reporting done directly to the Meteorological Department.

A study of Map 3 will show that the distribution of raingauges is not even throughout the country but is highly concentrated in the major agricultural regions. The network in the Irrawaddy Delta and in the Dry Belt is adequate for all but micro-studies. In the Shan Upland, as in the mountainous region to the west and north of the nation, the coverage is scanty indeed. Of particular note is the fact that nowhere in the country are raingauge stations located so as to provide data from various elevations across a mountain range.

One excellent possibility for a detailed study of rainfall differences with changing elevations appears to be along the road between Bhamo and Sinlumkaba in the Kachin State. The direct east-west distance between these towns is 17½ miles and a jeepable road connects the two. Bhamo, at an elevation of 350 feet, is the site of a full-time government observatory which could act to check the accuracy of data collected at the low point of the profile. Sinlumkaba, at 6052 feet, is the site of a government high school where well-educated and responsible observers could be found for the intermediate stations.

Another potential profile site lies along the road from Meiktila or Thazi, near the southeastern edge of the Dry Belt, along the road to Kalaw and Taunggyi in the Shan State. The straight line distance here would be about 65 miles and the difference in elevation would be slightly in excess of 5000 feet Government stations are established at each end of this profile and could serve to anchor the profile.

Very interesting results might be obtained from a profile between Kalemyo, in the Chindwin Valley, and Tiddim, in the Chin Special Division. Such a profile would start at an elevation of 650 feet, pass through Fort White, at an elevation of slightly over 7000 feet, cross the pass at 8000 feet and terminate at Tiddim, elevation 4000 feet Additional stations on such a profile might well extend three miles east of Tiddim to reach the Manipur River at an elevation of 1600 feet.


BURMA
SCALE IN MILES
• = RAINGAUGE STATION
USED IN STUDY
LASHIO
TAUNGGYI
AKYAB
KYAUKPYU
SANDOWAY
PROME
TOUNGOO
PAPUN
HENZADA
THAPRAWADDY
PEGU
THATUN
BASSEIN
MYAUNGMYA
PYAPON
MOULMEIN
AMHERST

MAP 3

Rainfall data are collected in Burma by several government agencies. At most stations raingauges are the only instruments in place. These gauges are normally of the standard 8" size and are well exposed in a fenced compound. Here at Taunggyi in the compound the Highway Department are located two raingauges, an anemometer, a weather vane, and a standard instrument shelter containing a barometer and maximum and minimum thermometers.
At stations such as this, full-time trained observers are employed. At smaller stations, part-time observers read the raingauges and report the findings to Rangoon

The road from Bhamo to Sinlumkaba offers excellent possibilities for a rainfall study profile. The road is open to jeeps at all seasons but during the rains it is sometimes subject to landslides as above.

The rainfall data collected by the various raingauge stations throughout the country are considered to be generally quite accurate although occasional typographical errors are to be found in the printed tables. Small variations in monthly and yearly "normal" figures are found from time to time in the records for almost every station as is illustrated by the example below.

Table 1.

Various Mandalay Rainfall Data 1.

	J	F	M	A	M	J	J	A	S	O	N	D	Year
a.	.1	.1	.2	1.2	5.8	6.3	2.7	4.1	5.4	4.3	2.0	.4	32.5
b.	.0	.1	.2	1.1	5.5	5.4	3.4	4.1	6.5	4.7	1.7	.3	33.3
c.	.0	.2	.2	1.4	5.9	5.9	2.8	4.0	5.8	5.0	2.5	.4	34.3
d.	.1	.1	.2	1.1	5.3	5.7	3.3	4.2	6.2	4.5	1.7	.3	32.5

1. Line A, data as recorded in "Statement Showing the Monthly and Annual Rainfall at Rain-Recording Stations in Burma for the Year 1954", same data is listed for the years 1950-1953; same data is used in the "Season and Crop Report of the Union of Burma" for the years 1951-1960. Line B, data as shown in "Technical Report EP-91", Quartermaster R. and E. Center, Natick, Mass., p. 18. Line c, data from "Rainfall Recorded at District Headquarters or at the Station Nearest to District Headquarters in Burma for the Month of — — — 1960", same data presented by M. Y. Nuttoson, "The Physical Environment and Agriculture of Burma", p. 19. Line d, "Climatological Tables for Burma" Rangoon, 1949 (reprint), pp 4-5

In part these small differences can be traced to a change in the location of the collecting point. For example, the official record for Mandalay was originally compiled at the University College campus, but at the end of World War II a new collecting point was established at Mandalay Airport. The new station has the same elevation and almost the identical exposure but is located one half mile due south of the older University College raingauge.

Differences in the "normal" data for some of the stations with records shorter than Mandalay's 60 years can be explained only by the gradual refinement of data as more and more records become available.

AVERAGE RAINFALL TOTALS

The most striking features of Burma's precipitation as shown on map 4 are the heavy rainfall totals along the Arakan and Tenasserim Coasts and the very low totals recorded in Central Burma. At Thaton and Tavoy on the Tenasserim Coast rainfall averages are 216 inches and 214 inches per year respectively while 10 miles to the south of Tavoy the village of Launglon records 226.23 inches per year, the highest average of any of the raingauge stations in Burma. This station, three and one-half miles inland from the coast, lies at an elevation of less than 500 feet above sea level. Twenty miles inland from Launglon and ten miles inland from Tavoy a range of hills parallel to the coast reaches an average crest line of 5100 feet. Undoubtedly precipitation totals on the windward flanks of this range are far higher than that recorded at Tavoy. Unfortunately the only available data is from coastal lowland stations. A profile of raingauges extending directly east from Tavoy to the valley of the Tenasserim River would yield interesting and valuable data on rainfall variations as influenced by topography.

The Arakan Coast, too, records very high annual totals and stations such as Akyab are often used in introductory texts as examples of extreme monsoon rainfall. At Akyab the long term annual average rainfall is 203 inches while Sandoway measures 212 inches. Again all of the 15 raingauges in this section of the country are located on the coastal lowlands or on the small offshore islands and none are at significant elevations on the Arakan Yoma. A trail leads almost directly across the Arakan Yoma from the coast behind Kyaukpyu to Minbu in the Dry Belt. The mountains between these stations reach heights of 5600 feet. Again no raingauges have been established along this profile and a study here would shed invaluable light on the question of rainfall variations with elevation on a mountain range lying directly athwart the monsoon winds. Travelers who are familiar with the road from Taungup to Prome, 75 miles south of the above proposed profile, report dramatic changes in rainfall, vegetation and land use potential from one side to the other of this considerably lower pass.

Map 4 shows heavy annual rainfall totals in the deltas of the Irrawaddy and Sittang Rivers. Heaviest rainfall is recorded on the extreme east and west margins of the compound delta. Thus, south of Bassein precipitation averages a little over 125 inches. But even greater totals are recorded at the eastern side of the delta along the edge of the Shan Upland. Here, orographic uplift combines with other rain producing mechanisms to yield 139 inches at Shwegyin in the Sittang Valley west of Papun. This station is located 15 miles east of the escarpment which reaches a height of 6000 feet in this area. Without question a gauge on the escarpment edge would show even higher totals.

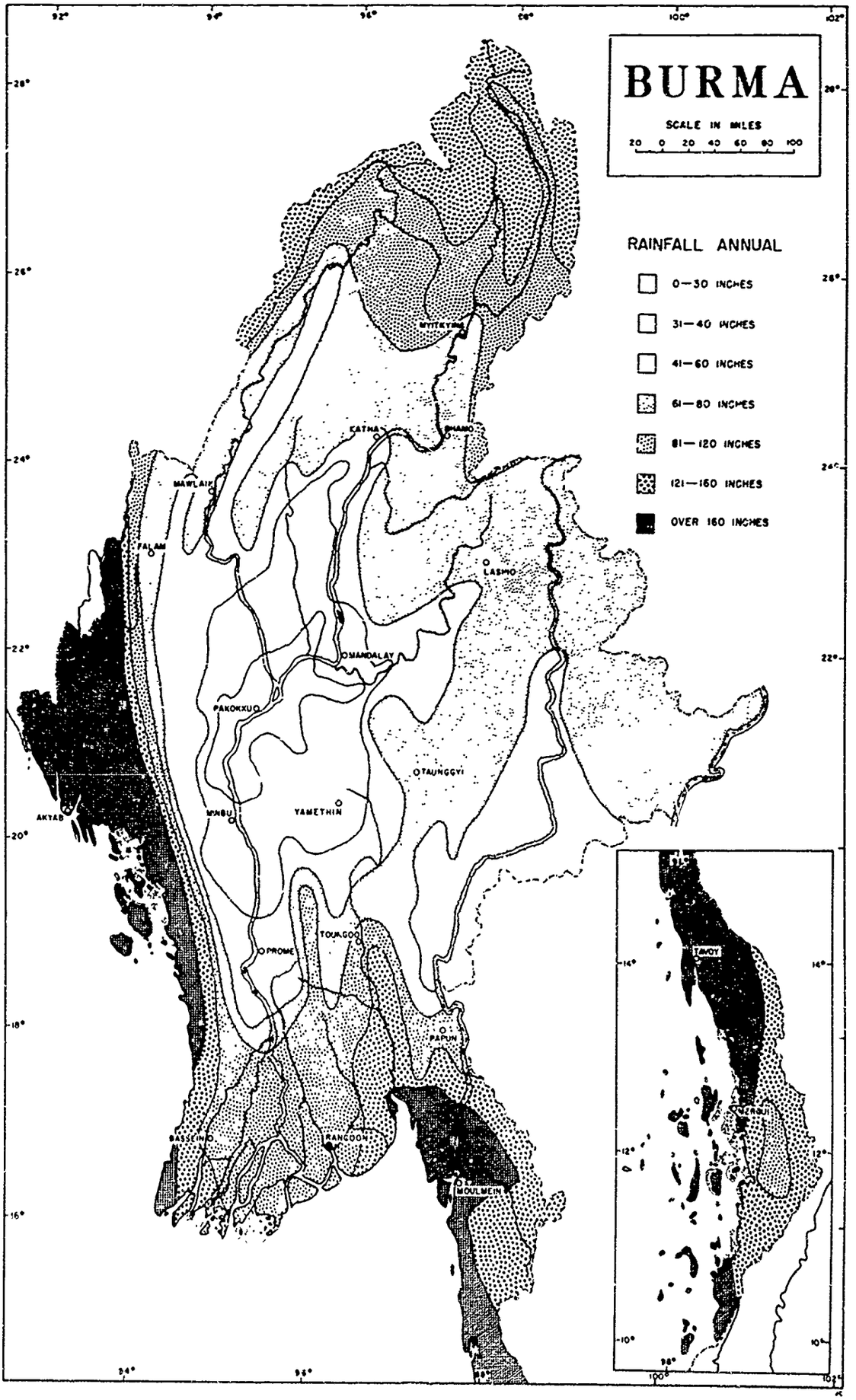
At the seaward edge of the middle of the Irrawaddy Delta rainfall totals are roughly 100 inches and northward from this point they decrease gradually with increasing distance from the sea, as may be seen in table 2.

Table 2.

Rainfall in Delta

Irrawaddy Valley	Rainfall in Inches	Miles from Edge of Delta	Same Latitude in Sittang Valley	Rainfall in Inches
Myaungmya	103	30		
Maubin	96	40		
Danubyu	87	75	Pegu	127
Henzada	84	100	Nyaunglebin	123
Myanaung	55	150	Pyu	119
Paungde	52	170		
Prome	47	200	Toungoo	83

This pattern is clear in the Irrawaddy Valley and is also noticeable in the Sittang. This latter valley however records higher totals at any given latitude than does the Irrawaddy for two reasons: uplift at the edge of the Shan Plateau and the rain shadow effect. Table 2 compares stations at similar latitudes in the two basins.


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINFALL ANNUAL
0—30 INCHES
31—40 INCHES
41—60 INCHES
61—80 INCHES
81—120 INCHES
121—160 INCHES
OVER 160 INCHES
MYITKYINA
KATHA
BHAMO
MAWLAIK
FALAM
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
AKYAB
MINBU
YAMETHIN
PROME
TOUNGOO
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

MAP 4

Separating the Irrawaddy from the Sittang drainage are the Pegu Yoma, a range of low hills. These provide some additional orographic cooling of the monsoon air masses and thus cause a northward bulge of the isohyets. The effect of these hills can be noticed on map 4 between Prome and Toungoo. This range influences precipitation almost as far north as Pakokku.

From Prome northward along the Irrawaddy Valley rainfall totals continue to decrease markedly to reach a minimum a few miles south of the confluence of the Chindwin with the Irrawaddy. This junction brings together the waters of two of Burma's greatest rivers in the center of a region which often suffers desperately from water shortages. Ironically neither of these rivers is used for irrigation. In earlier days the technology necessary for such development was not available and today capital adequate to the task is not to be had within the country. The dramatic drop in rainfall totals between Prome and the heart of the Dry Belt at Pagan is illustrated by table 3.

Table 3.

Rainfall in Dry Belt

Location	Rainfall in Inches	Number of Rainy Days
Prome	47	82
Sinbaungwe	32	65
Magwe	31	53
Yenangyaung	25	41
Seikpyu	24	34
Pagan	23	36

On the eastern side of the Central Lowland the drop in rainfall north from Toungoo is equally impressive in terms of percentage decrease but here the absolute minimum is nowhere as low as it is in the Irrawaddy Valley. This may be accounted for in part by the effect of the Shan Upland but perhaps of even greater significance are the föhn-like winds which blow down the lee slopes of the Arakan Yoma and cross the Irrawaddy lowlands. These winds not only increase the rate of evaporation in the Irrawaddy Valley but also mix with air flowing north from the delta region reducing its relative humidity and lowering its potential for precipitation. These föhn winds are blocked from access to the Sittang Valley and its northern counterpart, the Samon Valley, by the Pegu Yoma. Precipitation means are thus somewhat higher and potential evaporation somewhat lower to the east of the Pegu Yoma than to the west.

North of the latitude of Mandalay several hill ranges appear in the broad basin between the Irrawaddy and the Chindwin. Ranges such as the Sagaing Hills, the Kaukkwe Hills, the Loipyet Hills and the Mingin Range reach heights of several thousand feet and provide a mechanism for causing further orographic cooling and a gradual northward increase in precipitation. Northward of the latitude of Katha and Bhamo the orientation of Arakan Yoma changes, the mountains become known as the Naga Hills, the Letha Range and the Patkai Hills, and the crest lines converge toward the Putao Knot. From this latitude northward average annual precipitation increases markedly largely as a result of orographic squeeze combined with vigorous uplift. This increase may be noted in table 4.

Table 4.

Rainfall in North

Location	Rainfall in Inches	Number of Rainy Days
Mandalay	32	47
Singu	43	50
Katha	58	79
Bhamo	72	101
Myitkyina	80	105
Putao	154	151

In the Shan Upland data from 14 rain recording stations show annual averages ranging from 48 inches to 69 inches. The controlling factor appears to be exposure to prevailing winds and elevation. Of the stations with reliable data available Taunggyi shows the highest precipitation. It is of interest to note that the name Taunggyi directly translated into English means "big hill" and to note that this town is at an elevation of 4750 feet and in a position to be exposed to winds from the south and west. No other station on the Shan Upland is so exposed or is so elevated. There is little question but that higher elevations in this area receive even greater precipitation, but unfortunately no supporting data is available. On many a day this writer has strolled through the Taunggyi bazaar with no need of an umbrella while two miles to the west rainfall on the upper slopes of "the peak", 1000 feet above the town, was clearly visible.

The series of maps 5 through 16 show the pattern of "normal" rainfall by months over Burma. January is the dryest month. During this first month of the year the vast majority of the 228 raingauges operating intermittently throughout Burma report an average of less than .25 inches. In fact in any single year the report from most of the stations record rainfall as "nil". The long term averages do demonstrate however that rainfall on the order of .75 inches may be expected in the Naga Hills and over most of the Kachin State with the exception of the lowlands along the Irrawaddy River south of Myitkyina and the Hukawng Valley. In these latter areas and over the eastern two-thirds of the Shan Upland long term averages are between one-quarter and one-half inch.

The only other section of the country reporting over one-quarter inch is the coastal region from Mergui to Victoria Point at the extreme southern end of the country. Here again in at least 50 percent of the years of record no rainfall is recorded for the month.

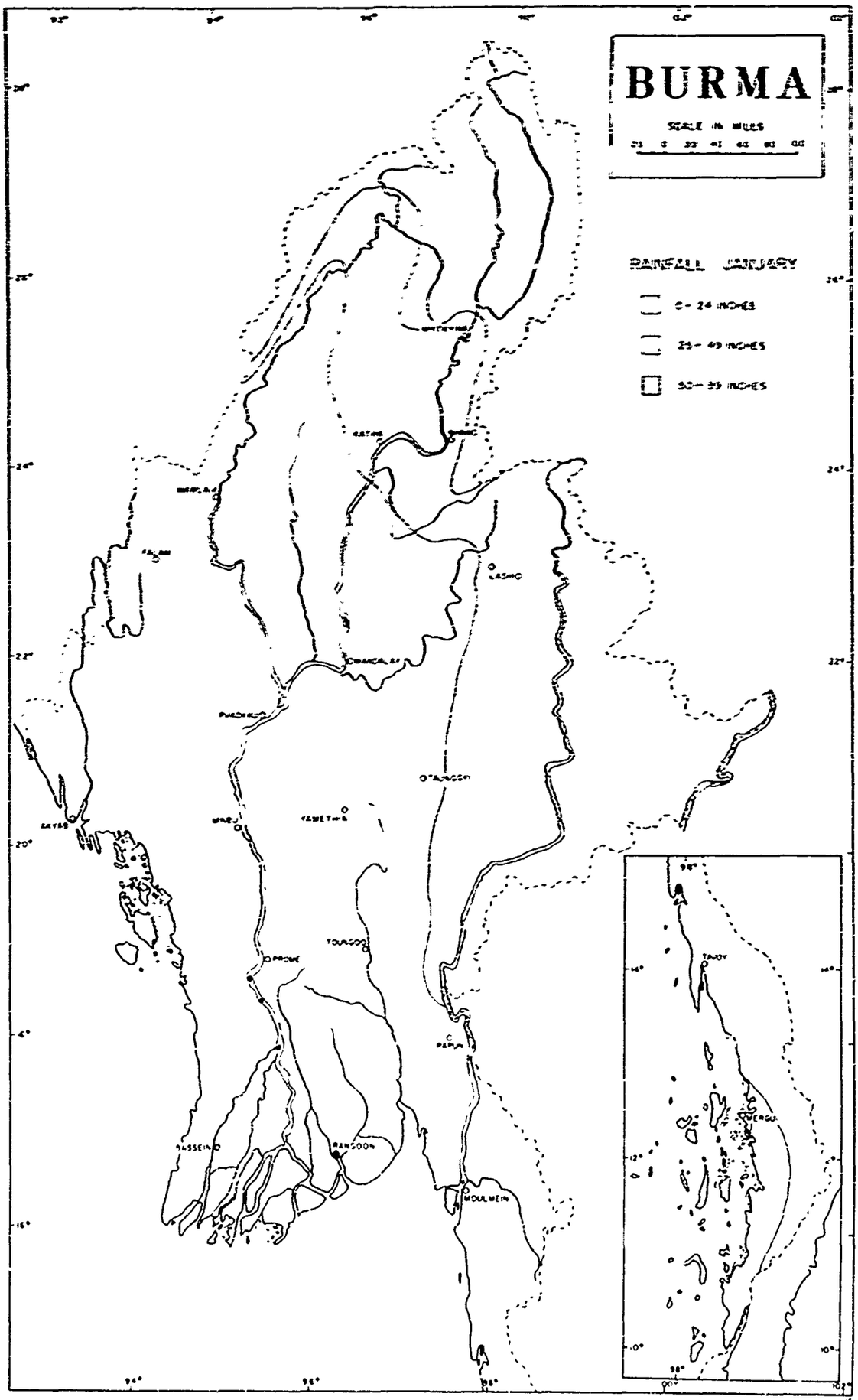
The pattern for February is similar to that of January but with greater rainfall and with a few interesting additions to the pattern. Maximum falls are still to be found in the mountainous sections of the Kachin State and the Naga Hills. Rainfall totals decrease markedly toward the south and, as in January, moderate precipitation is recorded in the eastern portion of the Shan Upland and in the coastal areas of Tenasserim. Once again Mergui in the far south is noticeable for its moderately abundant rainfall.

Variations from the January map are to be noted in the modest rainfall increases in the central portion of the Irrawaddy Delta, at the extreme southern end of the Pegu Yoma, at the northern end of the Arakan Coast and in the Chin Hills.

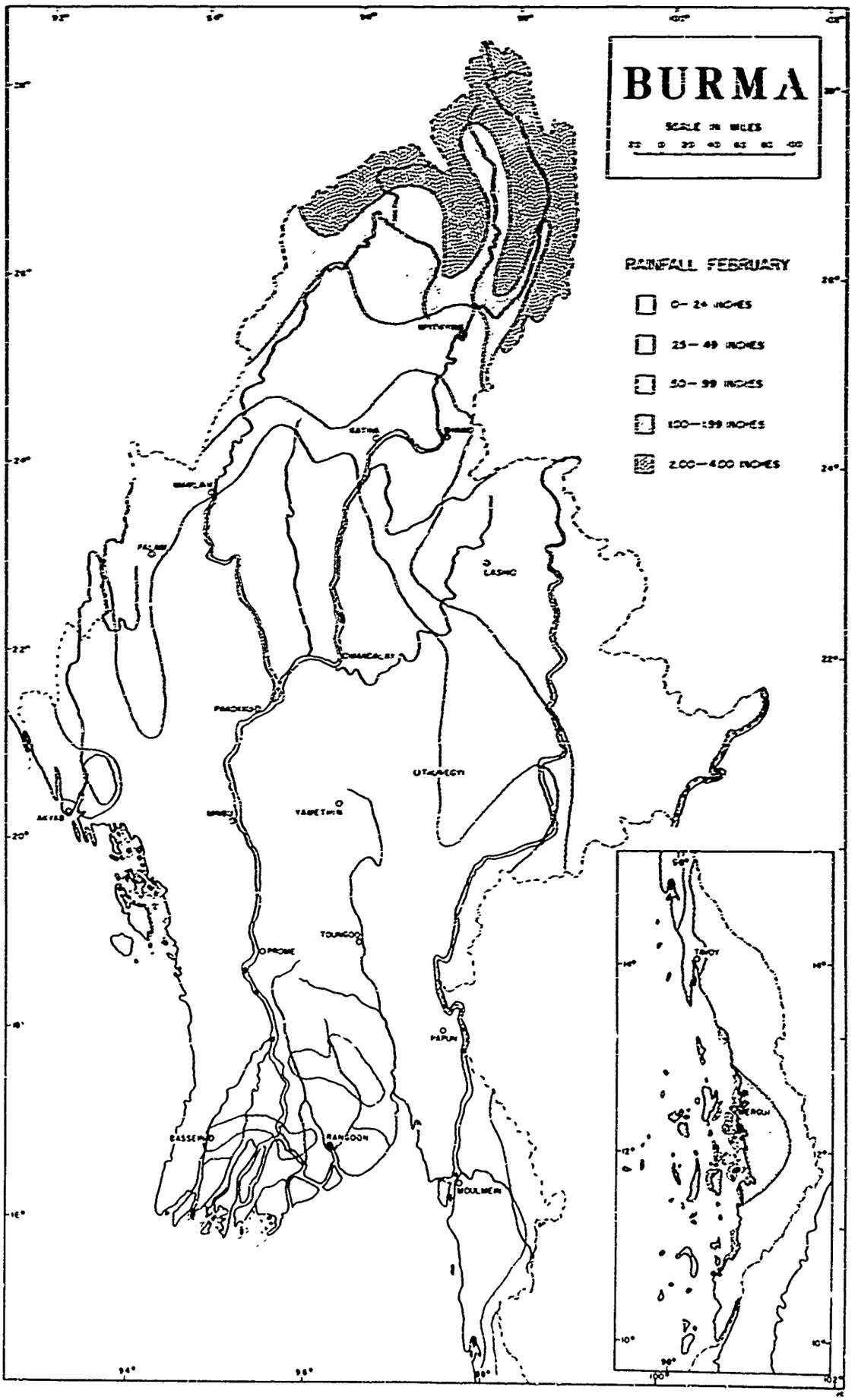
It will be recalled that during the winter season or the so-called "out monsoon" one of the causative factors appears to be the location to the south of the Himalaya of the jet stream. The location of the jet stream at this position, extending from northern Italy across the "Middle East", West Pakistan and India all the way to the latitude of the northern tip of Burma also acts to channel cyclonic disturbances along this path. A study of synoptic maps of India and Burma for the "winter" months demonstrates clearly that storms of Atlantic origin move through the Mediterranean and are trapped south of the mountain arc and the jet stream to bring rainfall to northern Burma from December to early April. Air masses drawn into the warm front of such storms from over the Gulf of Siam produce occasional widespread rainfall over the eastern portion of Burma's Shan State. This nominal precipitation is sufficient to yield the heavier dry season totals recorded in the area.

This early rainfall in the far north and the east of the country is of particular importance to the very numerous practitioners of taungya or shifting cultivation who inhabit these regions. This early rainfall keeps the forest moist thus helping to control the fires used to clear the newly cut areas. Perhaps more important, the cyclonic moisture enables the taungya to be planted and vegetative growth to be already underway prior to the onset of heavy monsoon rains. Erosion which otherwise might very soon denude the slopes is kept within manageable limits.

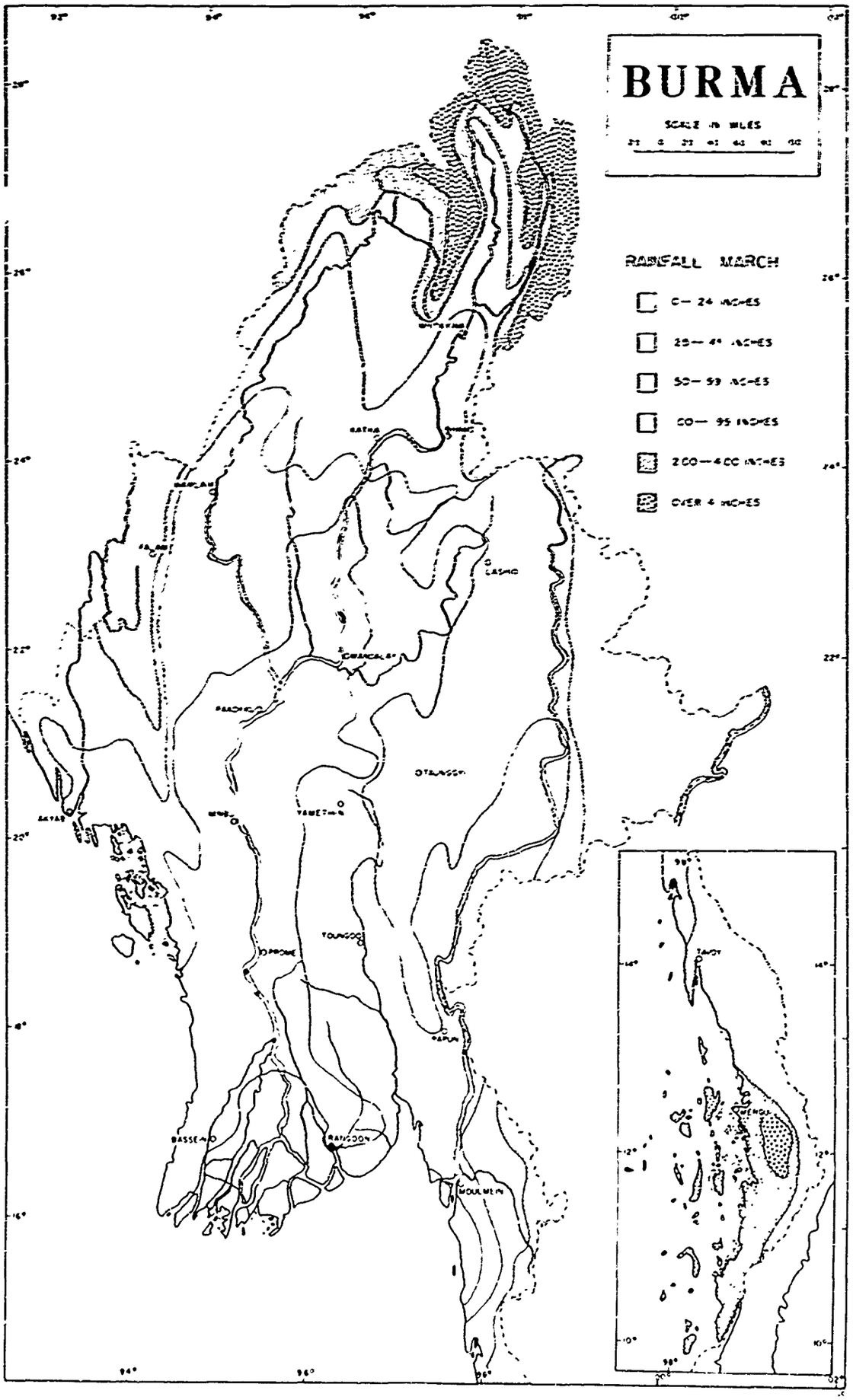
By mid-March the inter-tropical front has normally moved north of the equator sufficient distance to place it along a line extending from the Irrawaddy Delta across the Bay of Bengal to the island of Ceylon. March remains a dry month for Burma as a whole but at both the extreme south and the far north precipitation occurs in modest volume.


BURMA
SCALE IN MILES
RAINFALL JANUARY
0 - 24 INCHES
25 - 49 INCHES
50 - 99 INCHES
LASHIO
TAUNGGYI
YAMETHIN
TOUNGOO
PROME
PAPUN
RANGOON
MOULMEIN
TAVOY
MERGUI

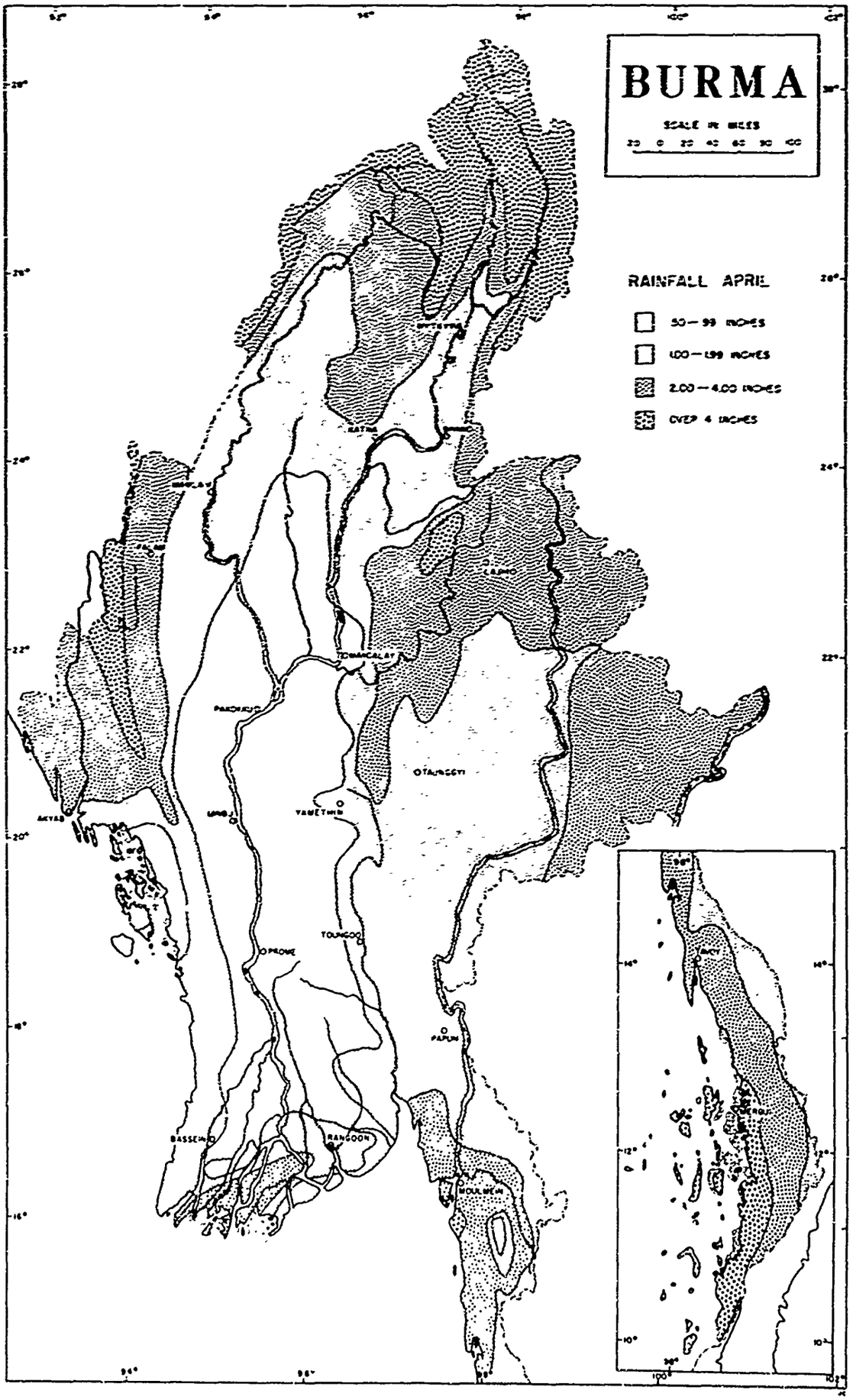
MAP 5


BURMA
SCALE IN MILES
RAINFALL FEBRUARY
0– 24 INCHES
25– 49 INCHES
50– 99 INCHES
100–199 INCHES
200–400 INCHES
LASHIO
YAMETHIN
TOUNGOO
PROME
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY

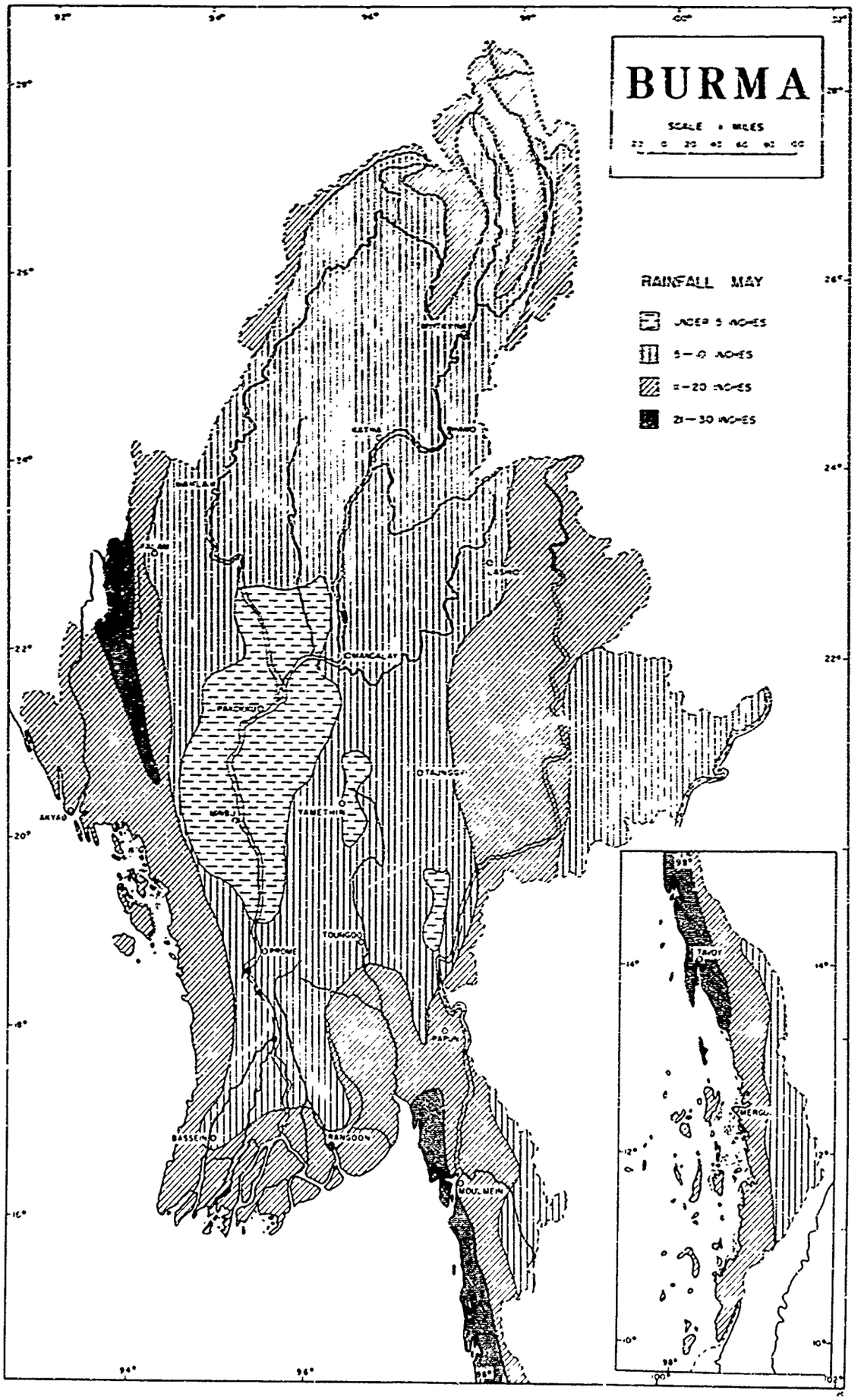
MAP 6


BURMA
SCALE IN MILES
RAINFALL MARCH
0— 24 INCHES
25— 49 INCHES
50— 99 INCHES
100— 95 INCHES
200—400 INCHES
OVER 4 INCHES
LASHIO
TAUNGGYI
YAMETHIN
TOUNGOO
PROME
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

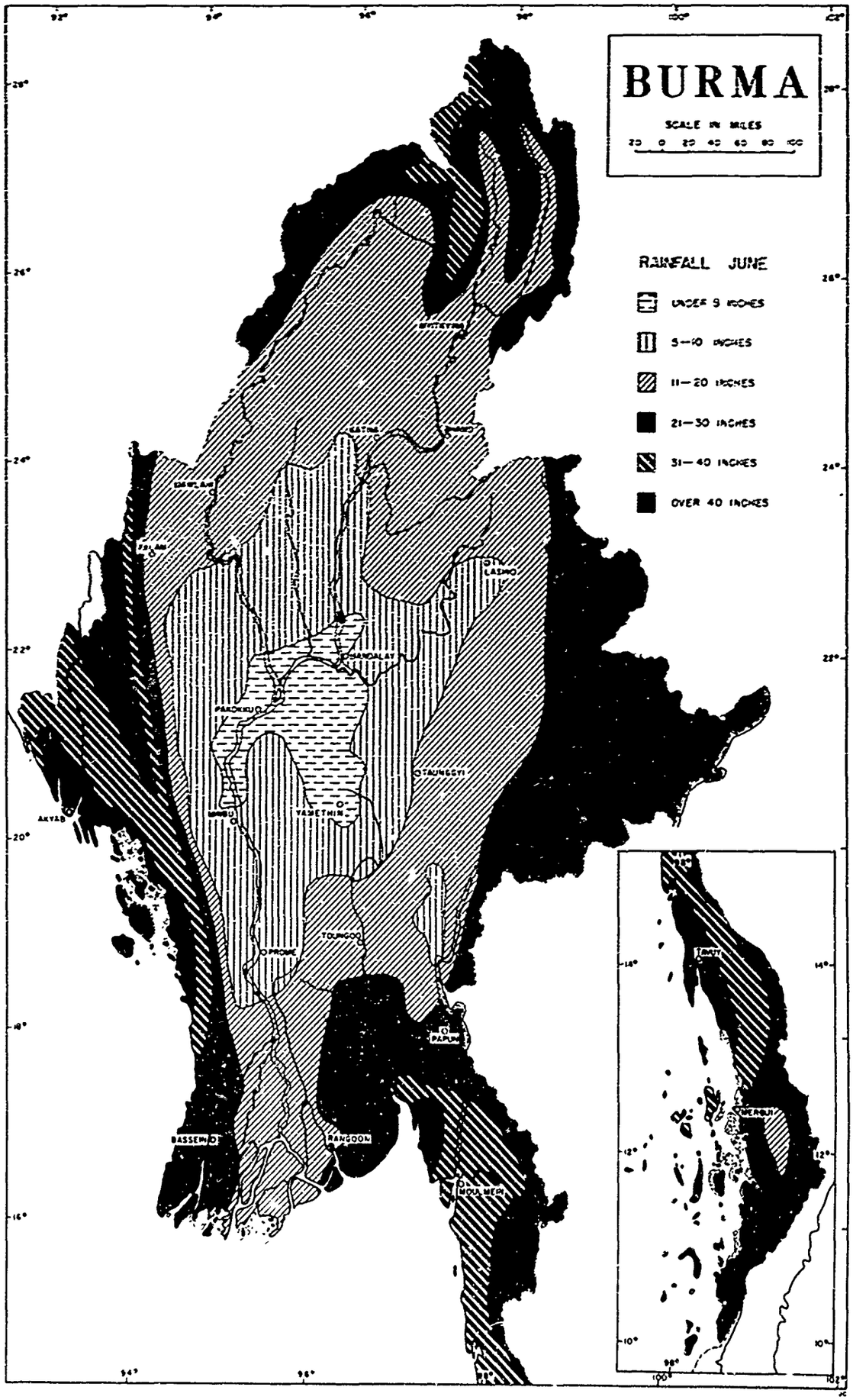
MAP 7


BURMA
SCALE IN MILES
RAINFALL APRIL
50—99 INCHES
1.00—1.99 INCHES
2.00—4.00 INCHES
OVER 4 INCHES
KATHA
LAJHO
MANDALAY
TAUNGGYI
YAMETHIN
TOUNGOO
PROME
PAPUN
BASSEIN
RANGOON
MOULMEIN
AKYAB

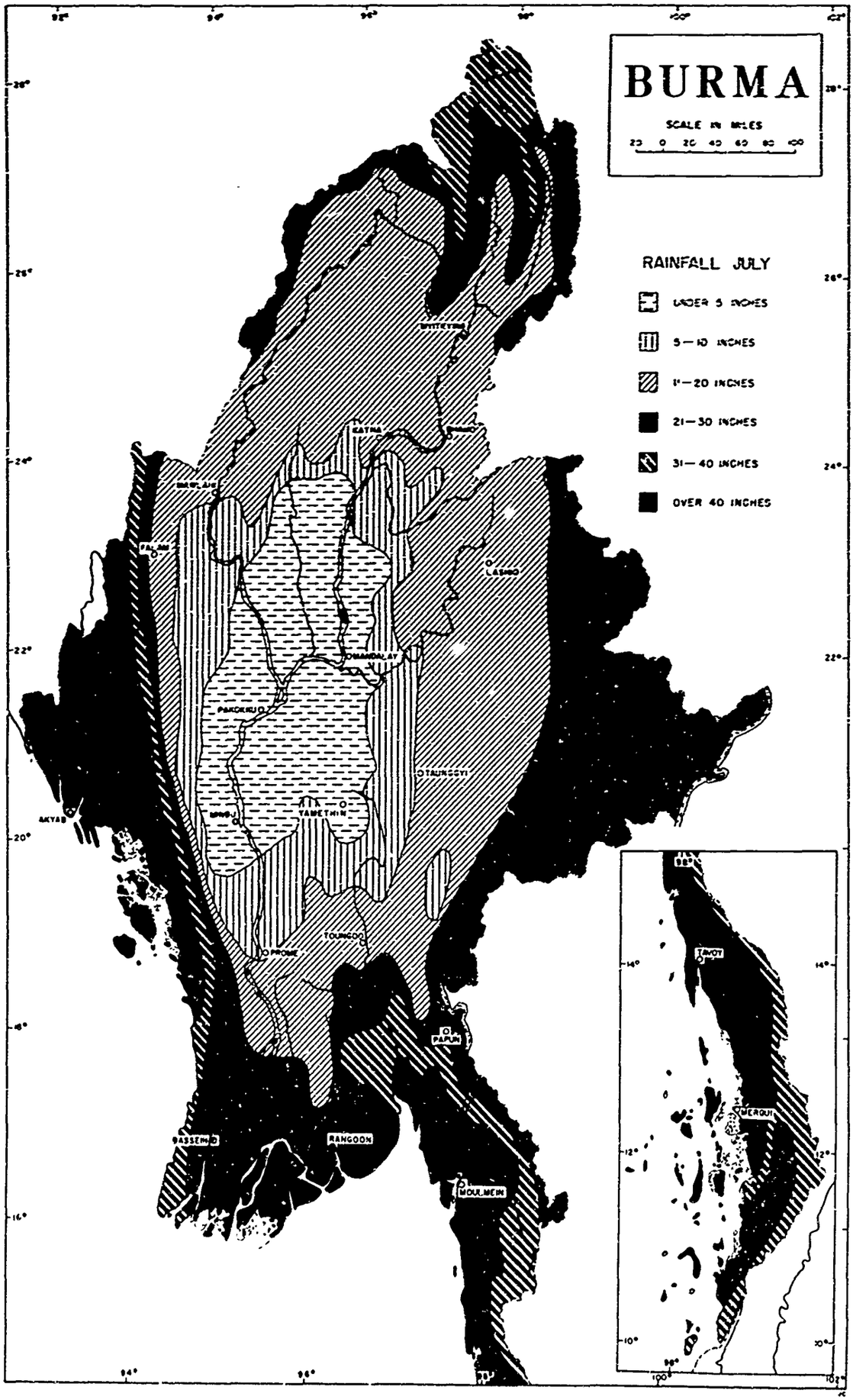
MAP 8


BURMA
RAINFALL MAY
21—30 INCHES
MANDALAY
YAMETHIN
TOUNGOO
PROME
BASSEIN
RANGOON
MOULMEIN
PAPUN
TAVOY
MERGUI

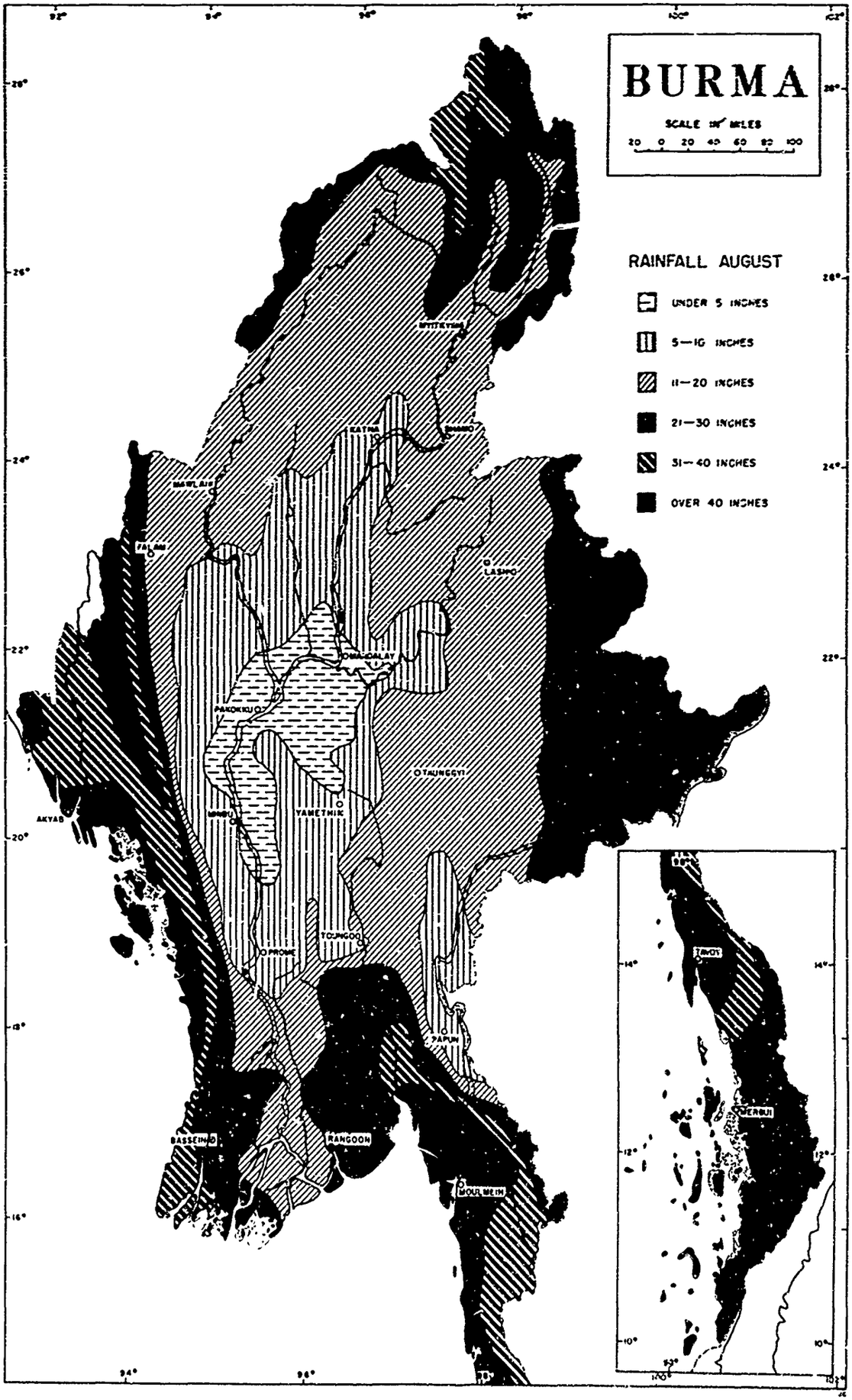
MAP 9


BURMA
SCALE IN MILES
RAINFALL JUNE
UNDER 5 INCHES
5—10 INCHES
11—20 INCHES
21—30 INCHES
31—40 INCHES
OVER 40 INCHES
MYITKYINA
KATHA
MANDALAY
PAKOKKU
TAUNGGYI
YAMETHIN
PROME
TOUNGOO
PAPUN
BASSEIN
RANGOON
MOULMEIN
AKYAB
SITTWAY
TAVOY
MERGUI

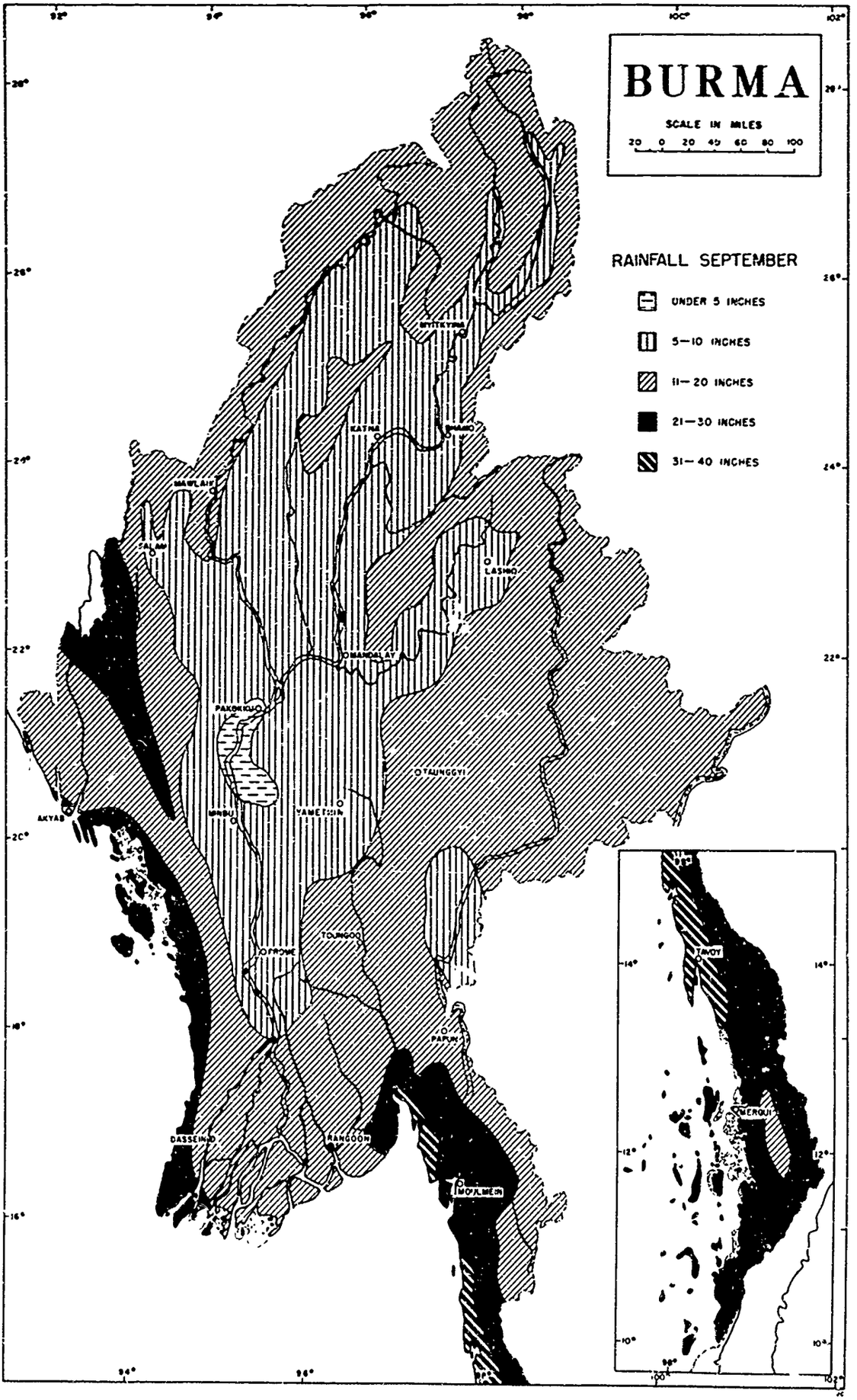
MAP 10


BURMA
SCALE IN MILES
RAINFALL JULY
UNDER 5 INCHES
5—10 INCHES
11—20 INCHES
21—30 INCHES
31—40 INCHES
OVER 40 INCHES
KATHA
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
YAMETHIN
AKYAB
TOUNGOO
PROME
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

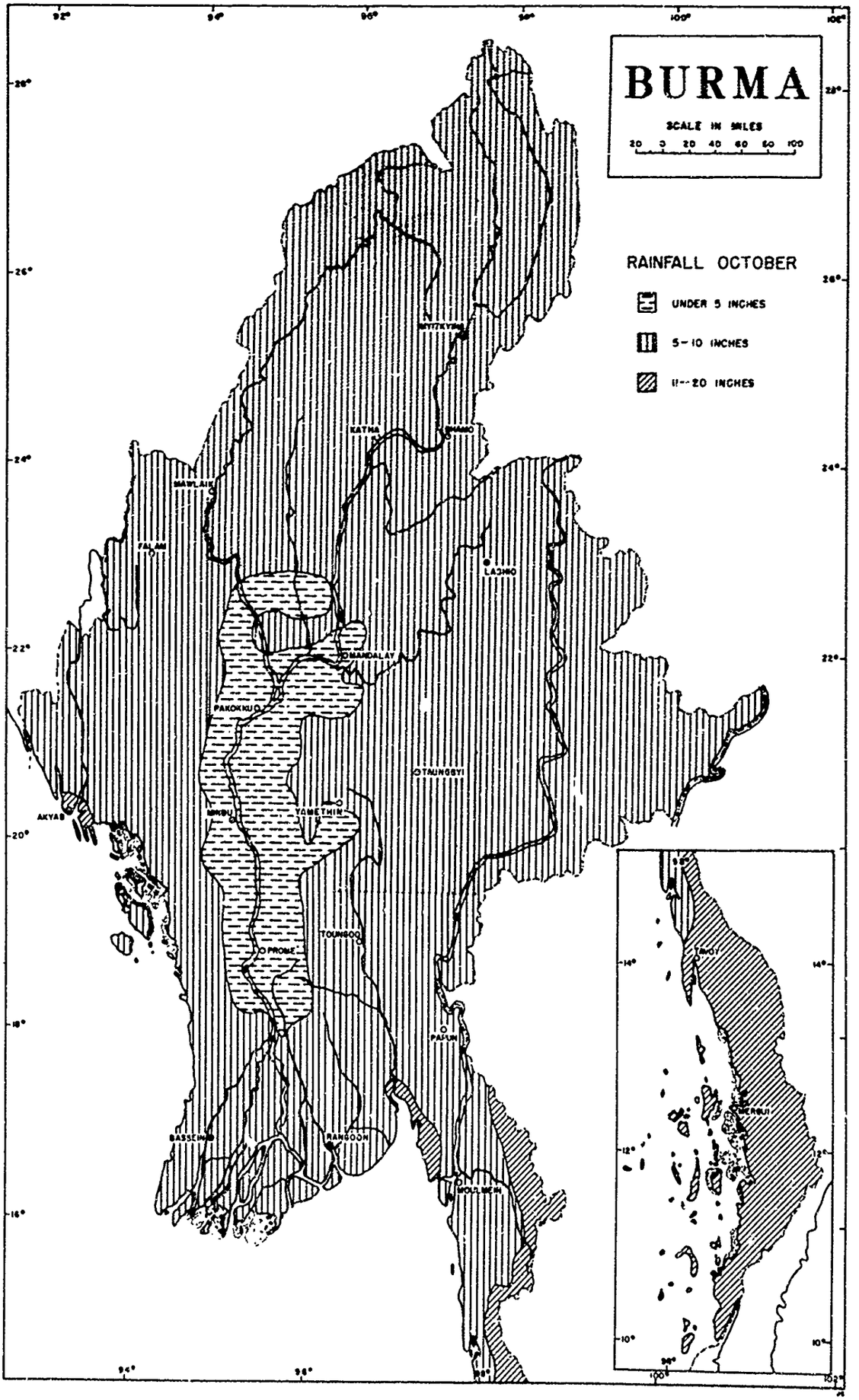
MAP 11


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINFALL AUGUST
UNDER 5 INCHES
5—10 INCHES
11—20 INCHES
21—30 INCHES
31—40 INCHES
OVER 40 INCHES
MYITKYINA
KATHA
BHAMO
MAWLAIK
FALAM
LASHIO
TAUNGGYI
PAKOKKU
YAMETHIN
AKYAB
PROME
TOUNGOO
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

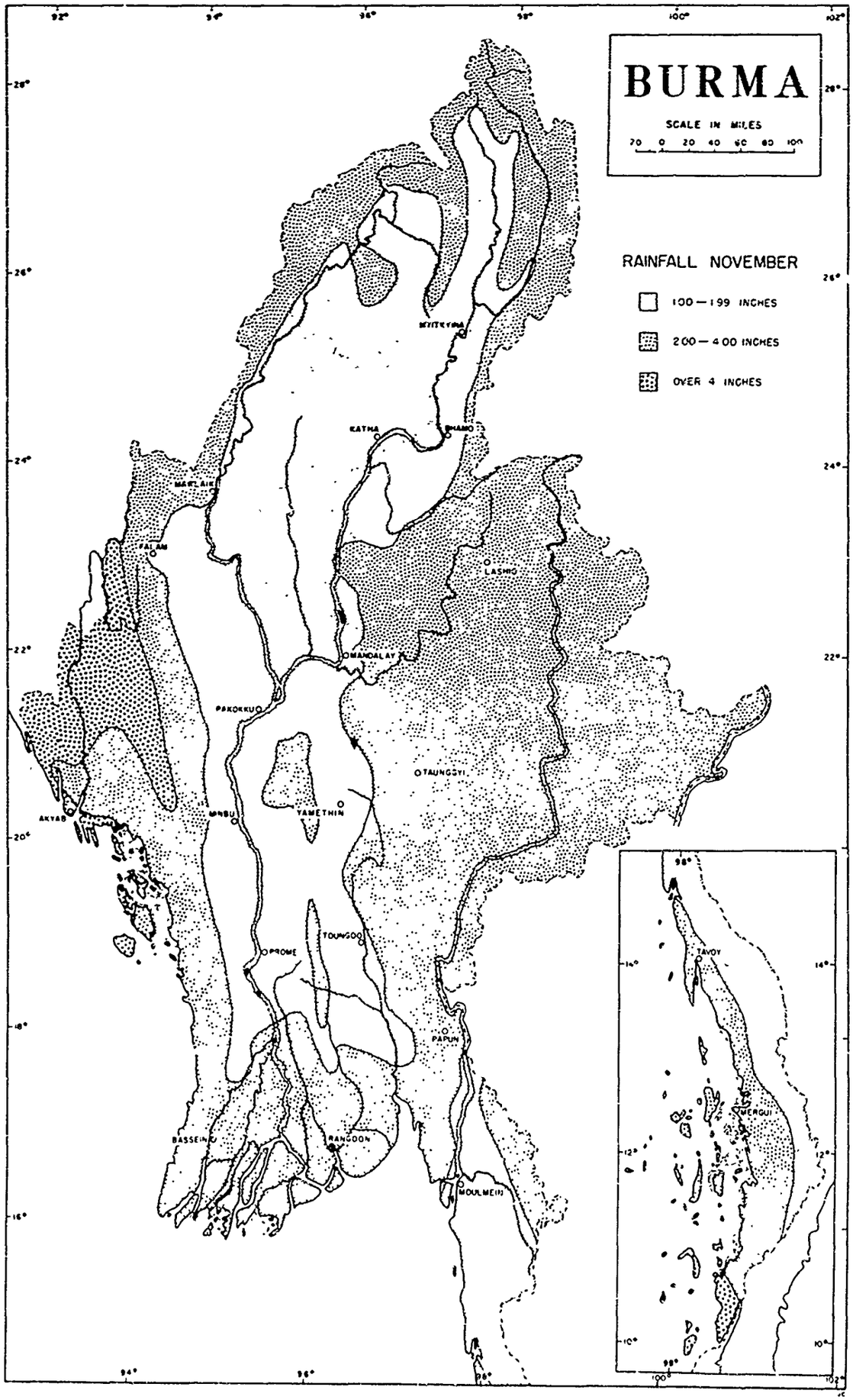
MAP 12


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINFALL SEPTEMBER
UNDER 5 INCHES
5—10 INCHES
11—20 INCHES
21—30 INCHES
31—40 INCHES
MYITKYINA
KATHA
BHAMO
MAWLAIK
SALAM
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
AKYAB
MINBU
YAMETHIN
TOUNGOO
PROME
PAPUN
DASSEIN
RANGOON
MOULMEIN
TAVOY
MERQUI

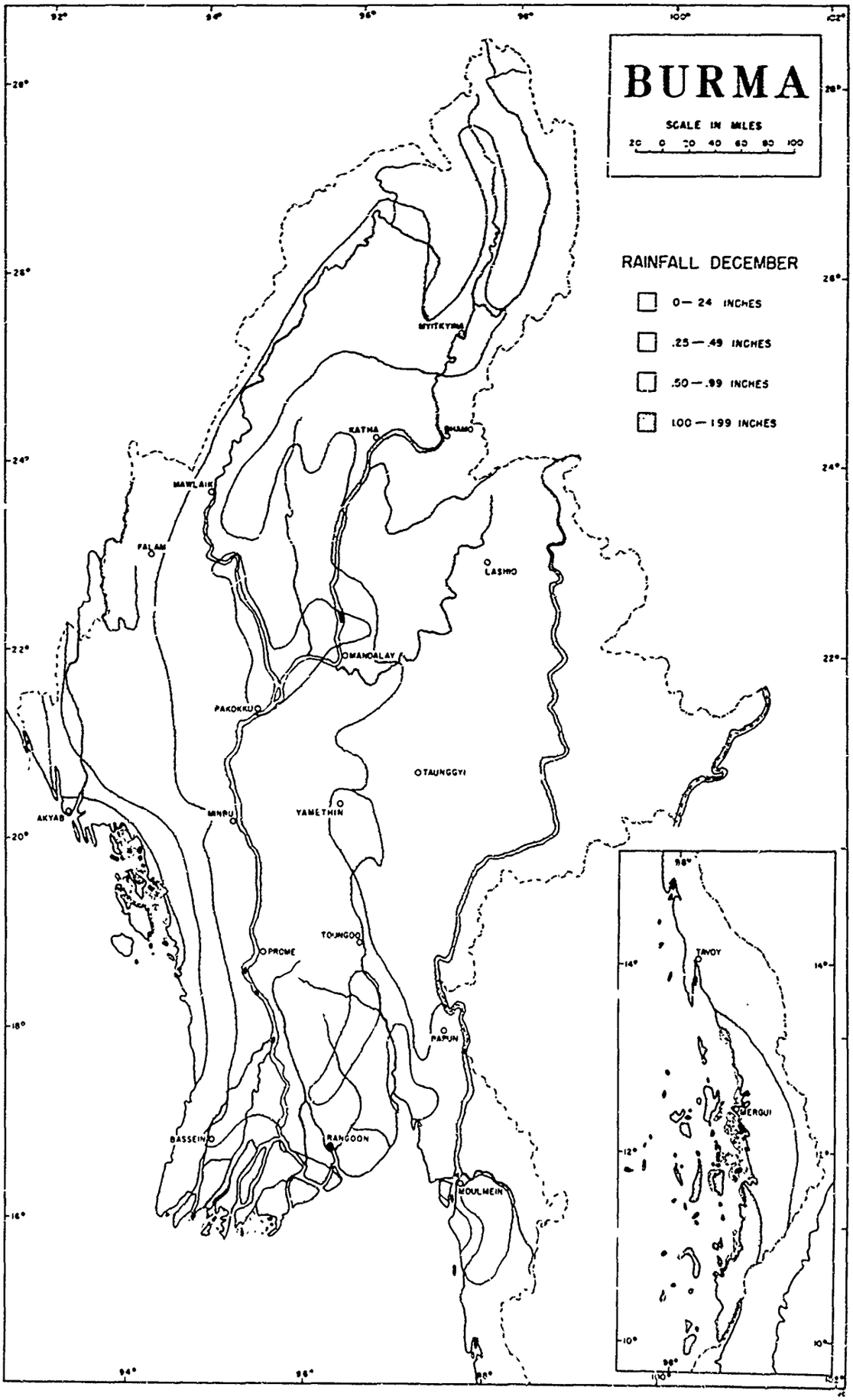
MAP 13


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINFALL OCTOBER
UNDER 5 INCHES
5-10 INCHES
11--20 INCHES
MYITKYINA
KATHA
MYNGYAN
MAWLAIK
FALAM
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
AKYAB
MINBU
YAMETHIN
TOUNGOO
PROME
PAPUN
BASSEIN
RANGOON
MOULMEIN
MERGUI
92°
94°
96°
98°
100°
102°
28°
26°
24°
22°
20°
18°
16°
14°
12°
10°

MAP 14


BURMA
SCALE IN MILES
70 0 20 40 60 80 100
RAINFALL NOVEMBER
100 — 199 INCHES
200 — 400 INCHES
OVER 4 INCHES
92°
94°
96°
98°
100°
102°
28°
26°
24°
22°
20°
18°
16°
14°
12°
10°
KATHA
PHAKO
MAKLAIK
FALAM
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
AKYAB
MINBU
YAMETHIN
PROME
TOUNGOO
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

MAP 15


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINFALL DECEMBER
0 — 24 INCHES
.25 — .49 INCHES
.50 — .99 INCHES
1.00 — 1.99 INCHES
MYITKYINA
KATHA
SHAMO
MAWLAIK
FALAM
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
AKYAB
MINBU
YAMETHIN
PROME
TOUNGOO
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

MAP 16

Taungya patches are scattered widely through the hill and mountain country of western and northern Burma. The pre-monsoon rains are of particular importance to farming in these areas.

To the south, especially in Mergui and Tavoy Districts, winds are quite variable during the month. Air flow from the sea together with some convectional activity combine to produce a March average of five inches of rainfall at the town of Tenasserim and slightly over three inches in much of the rest of the District, including the archipelago. Rainfall at this period, while other agricultural areas to the north are still quite dry, gives Mergui the shortest dry season in Burma and helps to assure the success of Burma's largest rubber plantations. In addition to rubber, Mergui is noted for the high quality and large volume of her equatorial fruits.

By the month of April the inter-tropical front has shifted eastward and lies in an almost north-south line across Viet Nam. During the month the flow of air from water to land becomes more marked, the frequency of development of convectional cells over the now much heated land areas becomes greater and rainfall, although not yet heavy, becomes more widespread. During April even the dry central Irrawaddy Valley shows averages of over one-half inch of precipitation. Minbu for example records an average of .77 inches in April but with average monthly temperature at 89 7 F., the highest of the year, this rainfall has very little effectiveness

Areas of high elevation in the north continue to demonstrate the highest falls in the country with stations north of Myitkyina reporting in excess of six inches. Rainfall of five inches in Mergui District is almost matched in April by the area around Moulmein with only slightly less than three inches

In May the air flow remains unsettled, heating of the land surface is intensive and monsoon winds begin to make their debut along the Tenasserim Coast where several stations show rainfall on the order of 21-28 inches. Along the Arakan Coast, in the Irrawaddy Delta and over portions of the Shan State, rainfall of from 11-20 inches is recorded. This normally occurs in showers of one hour or two in duration with considerable sunny periods interspersed. General cloud cover is not yet common.

During May the Dry Belt makes it first real appearance as may be noted by the area of dashed lines showing less than five inches of rainfall. Despite the low totals for the Dry Belt during this pre-monsoon period of April and May some rain does fall and this is of very great significance to farming in the area. At Pakokku the two month total is 3.59 inches while across the river at Myingyan the total is 4.18 inches. In both cases about 85 percent of the total occurs in May.

Synoptic charts show that during April and May the general flow of air from the surface to a level of approximately three kilometers is from the south, thus representing air from the Andaman Sea, air which contains modest volumes of moisture. This air is apparently drawn to the dry belt by the thermally induced low pressure created as a result of the very high afternoon surface temperatures. At levels higher than 3 kilometers the air flow is from north to south, representing very dry continental air masses.

Such conditions result in marked instability over the Dry Belt. Afternoon and evening thunderstorms are common over the region, especially in May, and are responsible for most of the rain that occurs during the month.

June, July and August are the months most typical of the southwest monsoon. During these months the flow of air from the Bay of Bengal onto the land area of the country is very well developed and almost uninterrupted. Air flow is generally from the southwest to the northeast. However where the smooth flow is broken by mountain barriers as along the Tenasserim Coast the main flow turns almost due north to reach the Irrawaddy-Sittang Delta from the south. Along the Arakan Coast part of the southwest monsoon wind traverses the hills and part is deflected toward the Ganges Delta.

July is typical of conditions during these months and reference to map 11 shows a number of striking features. On the Tenasserim Coast between Mergui and the mouth of the Sittang River the monsoon winds reach the hills with a high moisture content and with remarkable consistency. Orographic cooling combined with convectional activity and the passage of a number of "lows" combine to produce rainfall averages of about fifty inches at a number of locations. Along the Arakan Coast the situation is similar but here July rainfall is slightly heavier with several stations measuring in excess of 60 inches.

Air masses moving north up the Irrawaddy and Sittang Valleys lose moisture largely through the action of the depressions active in the monsoon flow and by convectional cooling. Rainfall in the delta averages some 22 inches in each of the three months June-August and this total decreases with increasing distance from the sea as has been pointed out.

By the middle of September the force and consistency of the monsoon winds has decreased and the monsoon has begun its "retreat". In September rainfall on the Arakan Coast averages only 23 or 24 inches, not dry by any means but well below the maximums recorded in the three earlier months. At the same time rainfall along the Tenasserim Coast averages slightly in excess of 31 inches.

One of the most interesting features of the September map is that at this month the Dry Belt receives its greatest rainfall. The area measuring less than five inches is confined to the region between Pakokku and Minbu, or only about 1/6 of the area dry in August.

October, November and December show no unexpected patterns. They demonstrate the effect of the continually weakening and retreating southwest monsoon and the emergence of the northeast winds as the dominating air mass. From October through December the rainfall pattern is similar with the only change being in terms of the amount.

January starts the annual cycle once again and is the dryest month of the year.

NUMBER OF RAINY DAYS

Maps 17 through 29 portray the pattern of annual and monthly normal number of rainy days. As might be expected the patterns on these maps are roughly the same as on the maps of total rainfall.

On the map of total yearly number of rainy days the Dry Belt of Central Burma shows up well and is centered along the Irrawaddy River near the town of Pakokku. At that station the normal number of rainy days per year is 38 while the total rainfall is 23.91 inches. Thus Pakokku receives an average of .63 inches per rainy day.

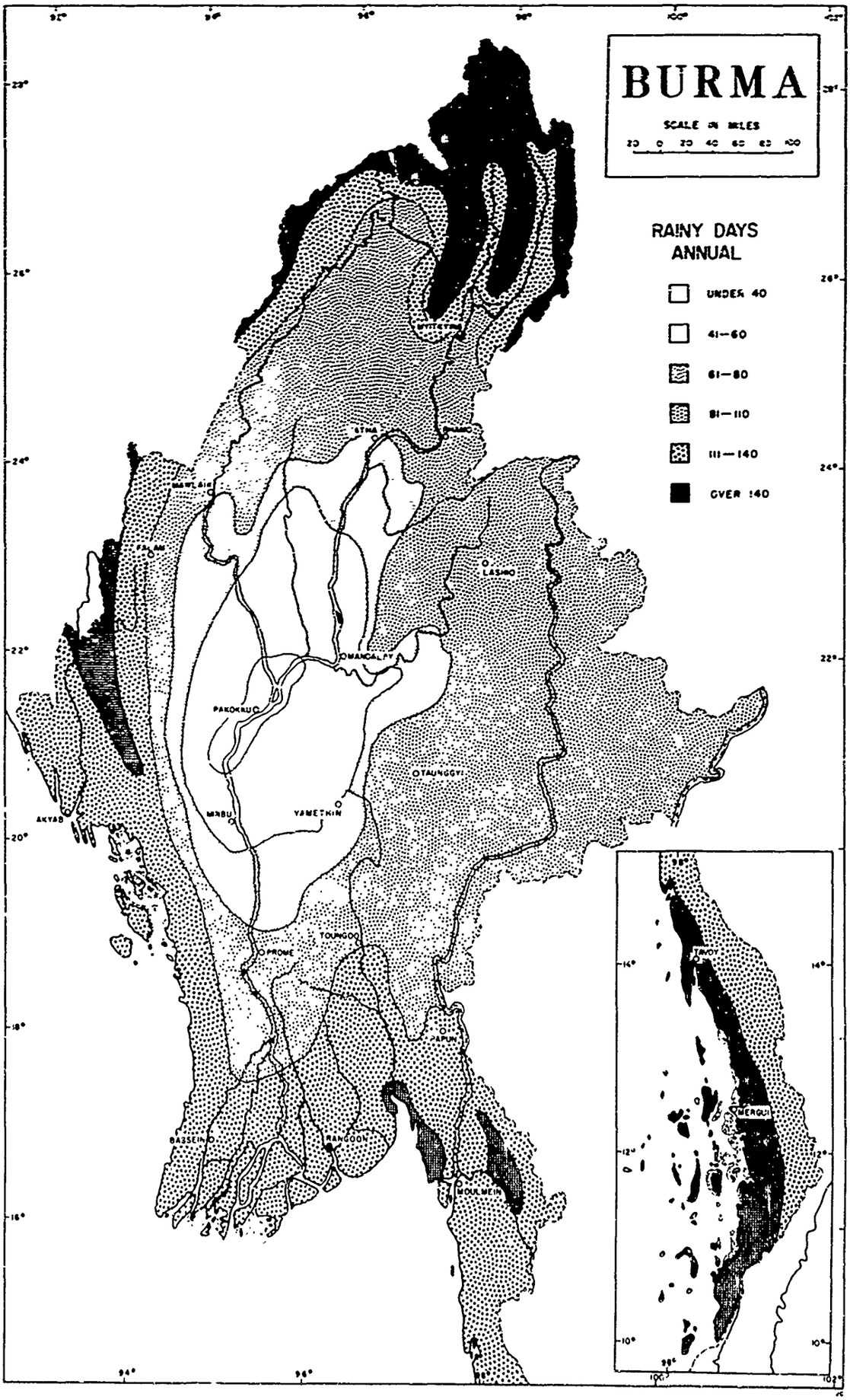
Victoria Point, at the extreme southern tip of the Tenasserim Coast has the greatest number of rainy days in all of Burma, 157, and records 166.5 inches of rainfall, an average of 1.06 inches per rainy day. Stations along the Arakan average about 125 rainy days per "normal" year and record the heaviest falls per day. Thus Akyab records 1.62 and Sandoway 1.71 inches of rainfall per rainy day.

For the country as a whole January is usually the month showing the least number of station days of rainy weather. During the month the majority of the 228 stations show an average of less than one wet day. Only in the Kachin State, north of Bhamo, do figures reach significant size. Here the mountains along the China border record wet periods about 1 day out of 10. In lower areas of the State, records show only one wet day in 16 for the Kachin State. In the far south, along the coastal areas of Mergui District, one wet day is expected every two weeks in January.

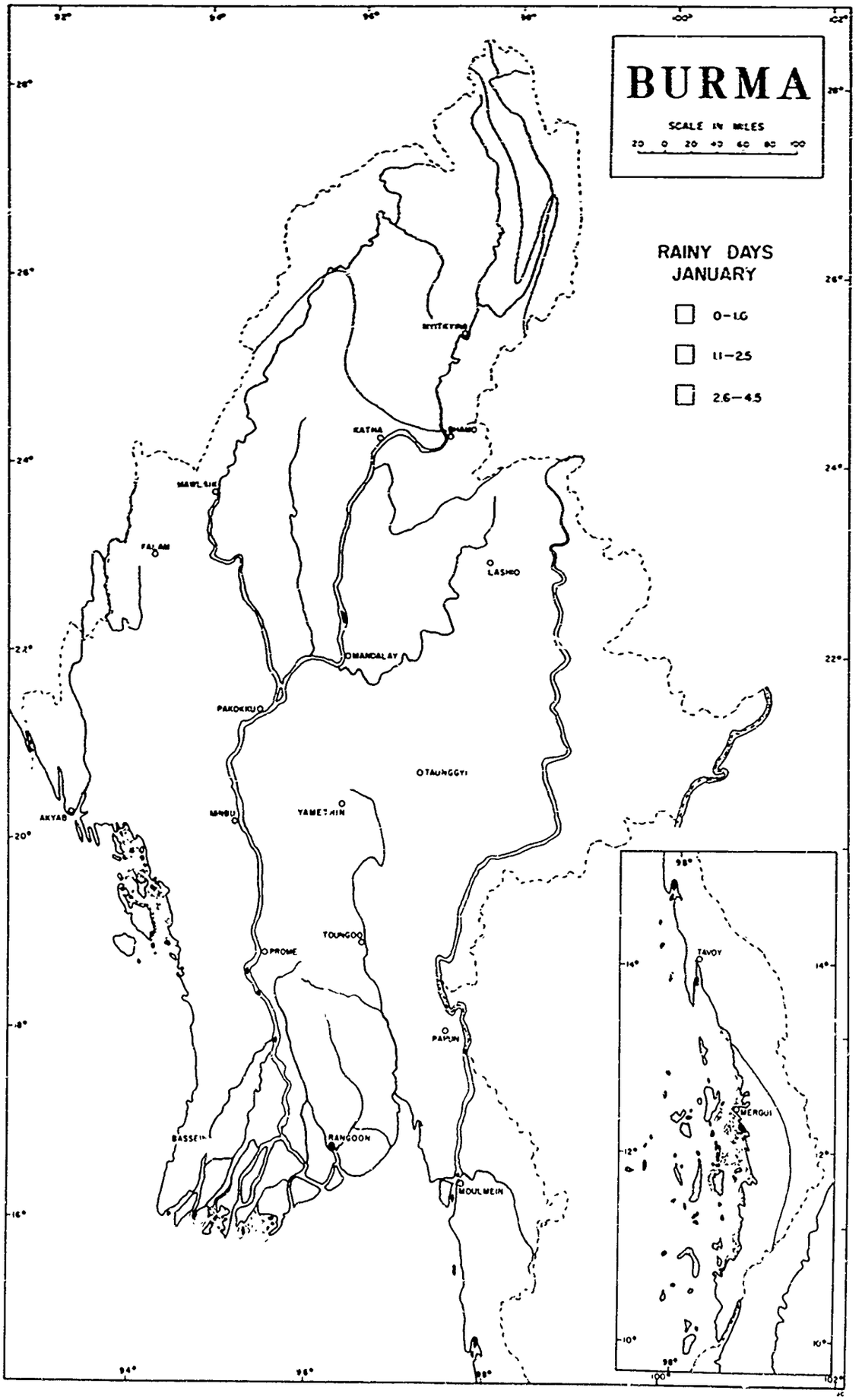
Through the months of February and March the number of rainy days increases gradually in that third of the nation north of Mandalay and along the Tenasserim Coast as may be observed on maps 19 and 20. The remainder of the country maintains dry weather with only modest cloud cover and rapidly increasing temperatures. In this area rainy days during the first quarter of the year are rare indeed.

In April the expected number of rainy days continue to increase in the upland areas of eastern, northern and northwestern Burma. During the month the lowlands, too, begin to experience a wet day every two weeks as may be seen on map 21.

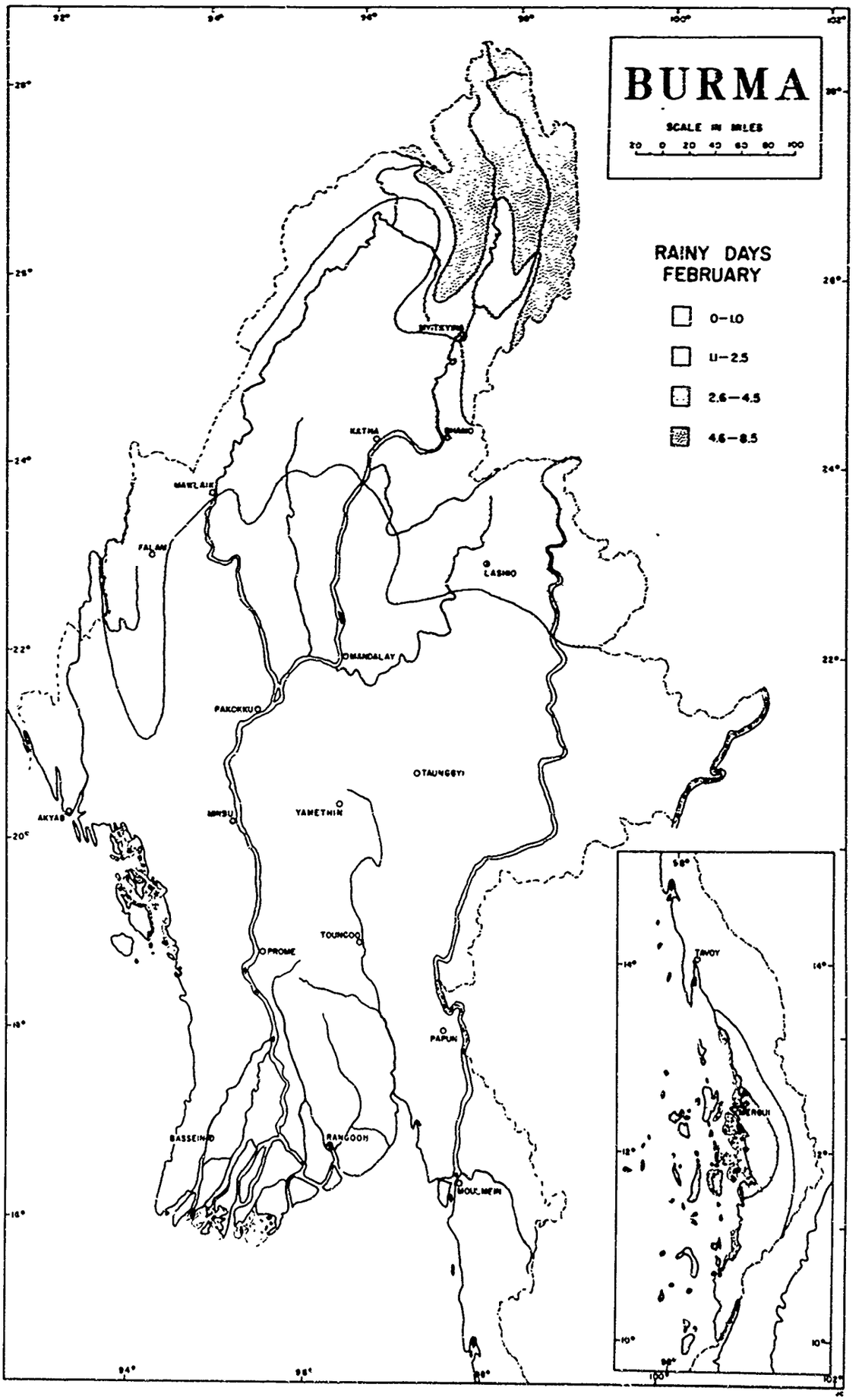
May and June are months of rapid build-up in the frequency of rainy days. The maximum is reached in July and August after which the frequency tapers off. It is of interest to note that the build-up of rainfall through March, April and May is more rapid and more marked than is the decrease in number of rainy days during September, October and November.


BURMA
SCALE IN MILES
RAINY DAYS
ANNUAL
UNDER 40
41—60
61—80
81—110
111—140
OVER 140
MYITKYINA
ETHA
MAWLAIK
FALAM
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
YAMETHIN
MINBU
AKYAB
TOUNGOO
PROME
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

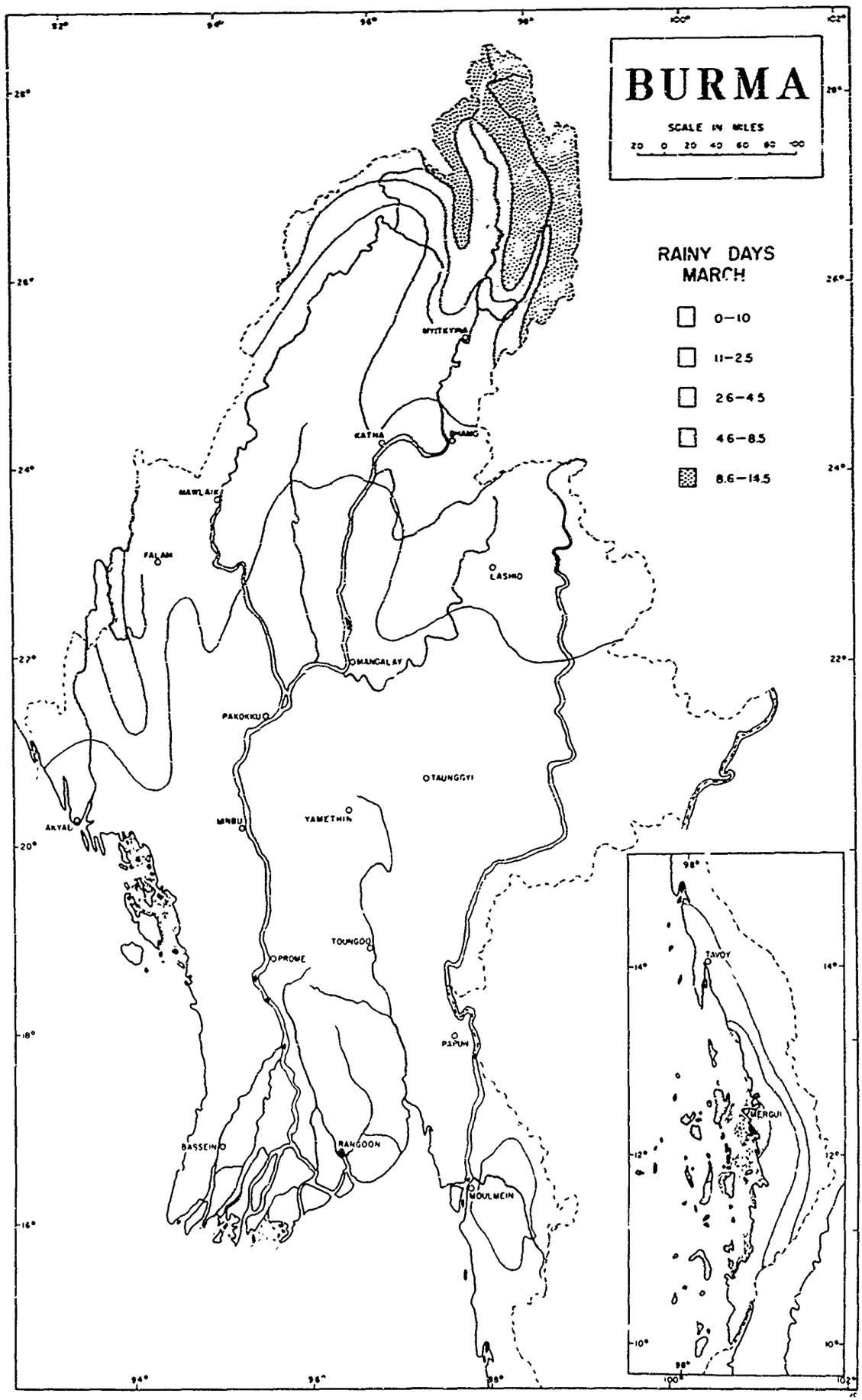
MAP 17


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINY DAYS
JANUARY
0-1.0
1.1-2.5
2.6-4.5
KATHA
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
YAMETHIN
PROME
TOUNGOO
PAPUN
AKYAB
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

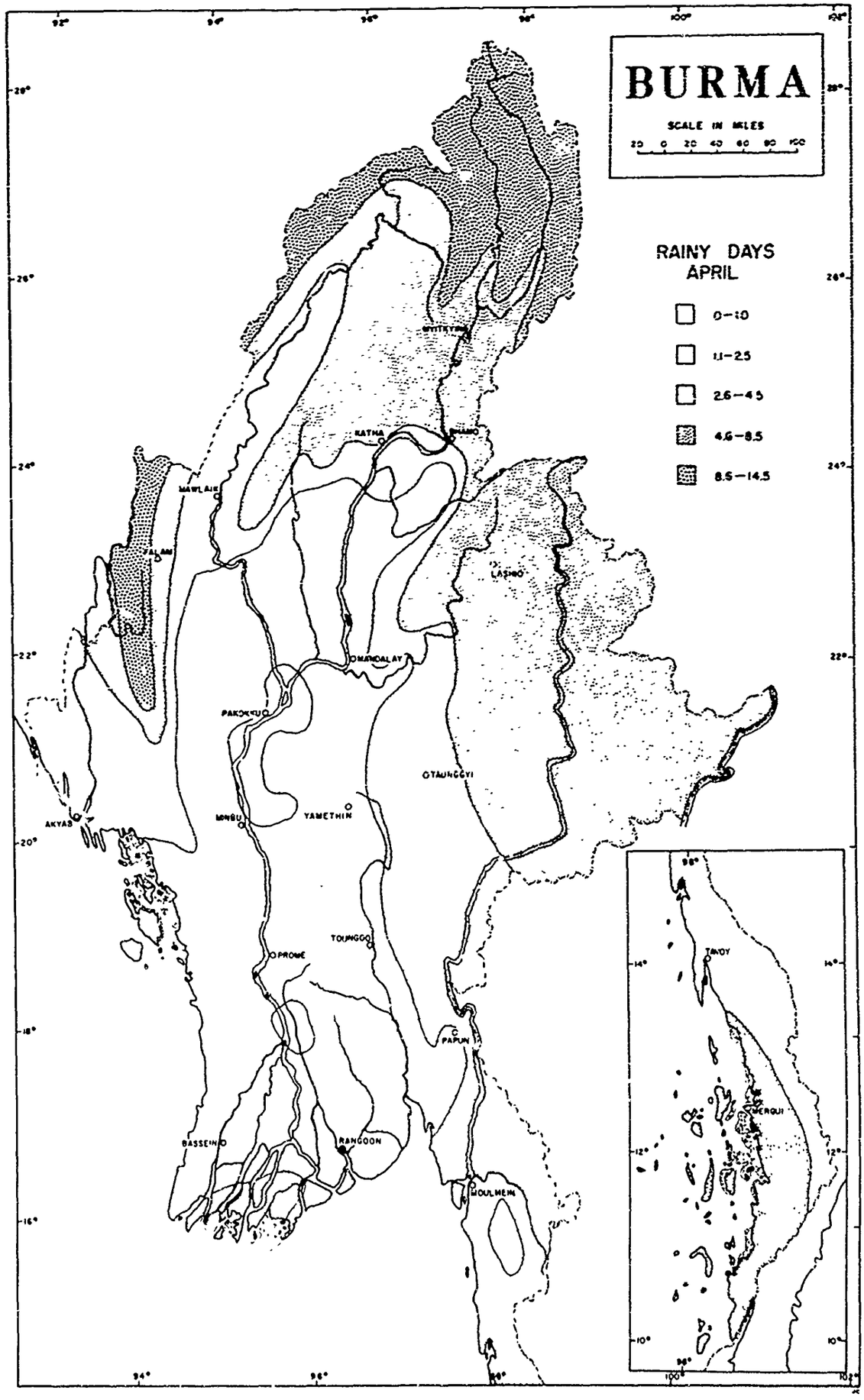
MAP 18


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINY DAYS
FEBRUARY
0-1.0
1.1-2.5
2.6-4.5
4.6-8.5
MYITKYINA
KATHA
BHAMO
MAWLAIK
FALAM
LASHIO
MANDALAY
PAKOKKU
OTAUNGGYI
AKYAB
MRUK U
YAMETHIN
TOUNGOO
PROME
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI
92°
94°
96°
98°
100°
102°
28°
26°
24°
22°
20°
18°
16°
14°
12°
10°

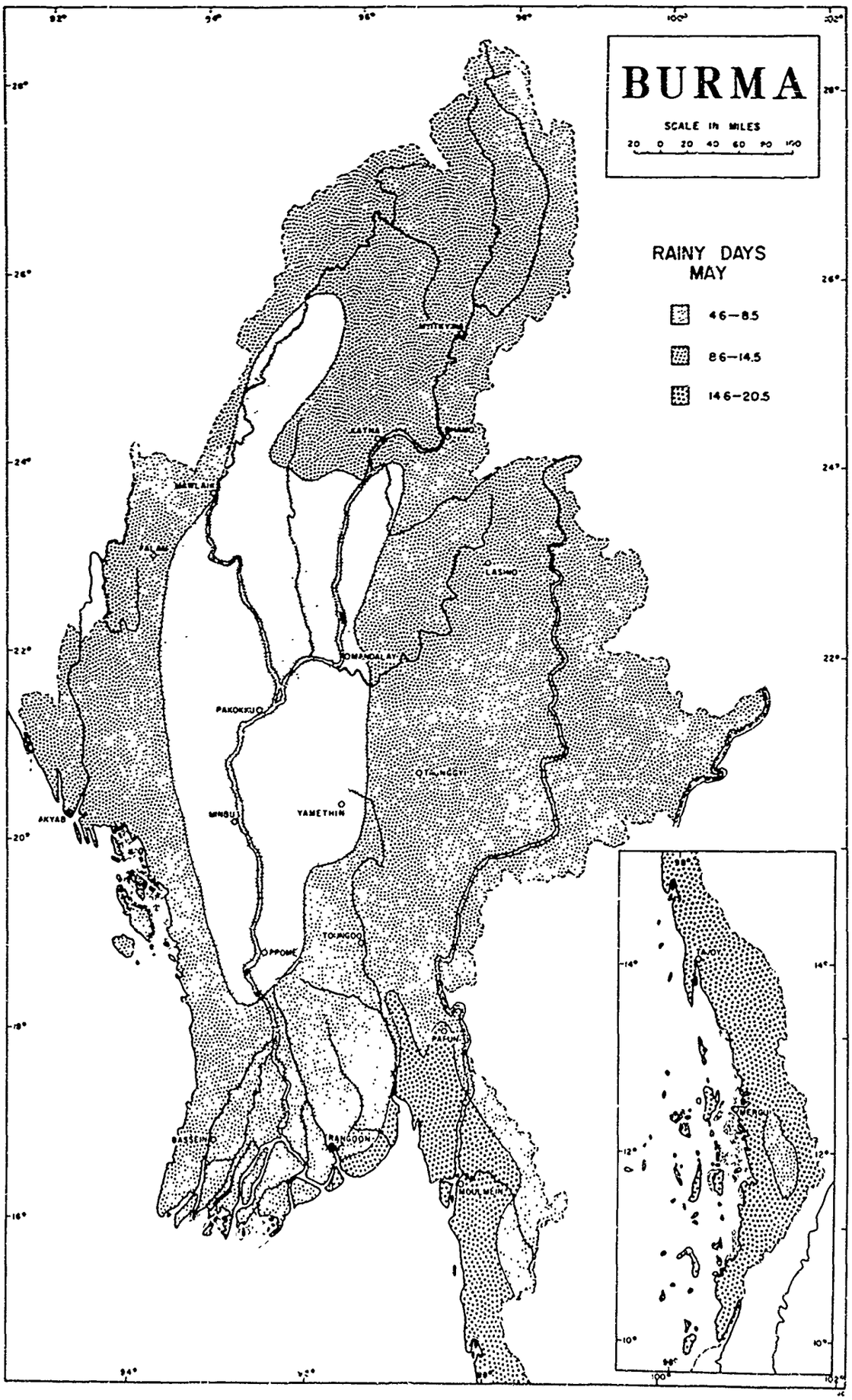
MAP 19


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINY DAYS
MARCH
0–10
11–25
26–45
46–85
86–145
MYITKYINA
KATHA
MAWLAIK
FALAM
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
ANYAL
MINBU
YAMETHIN
PROME
TOUNGOO
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

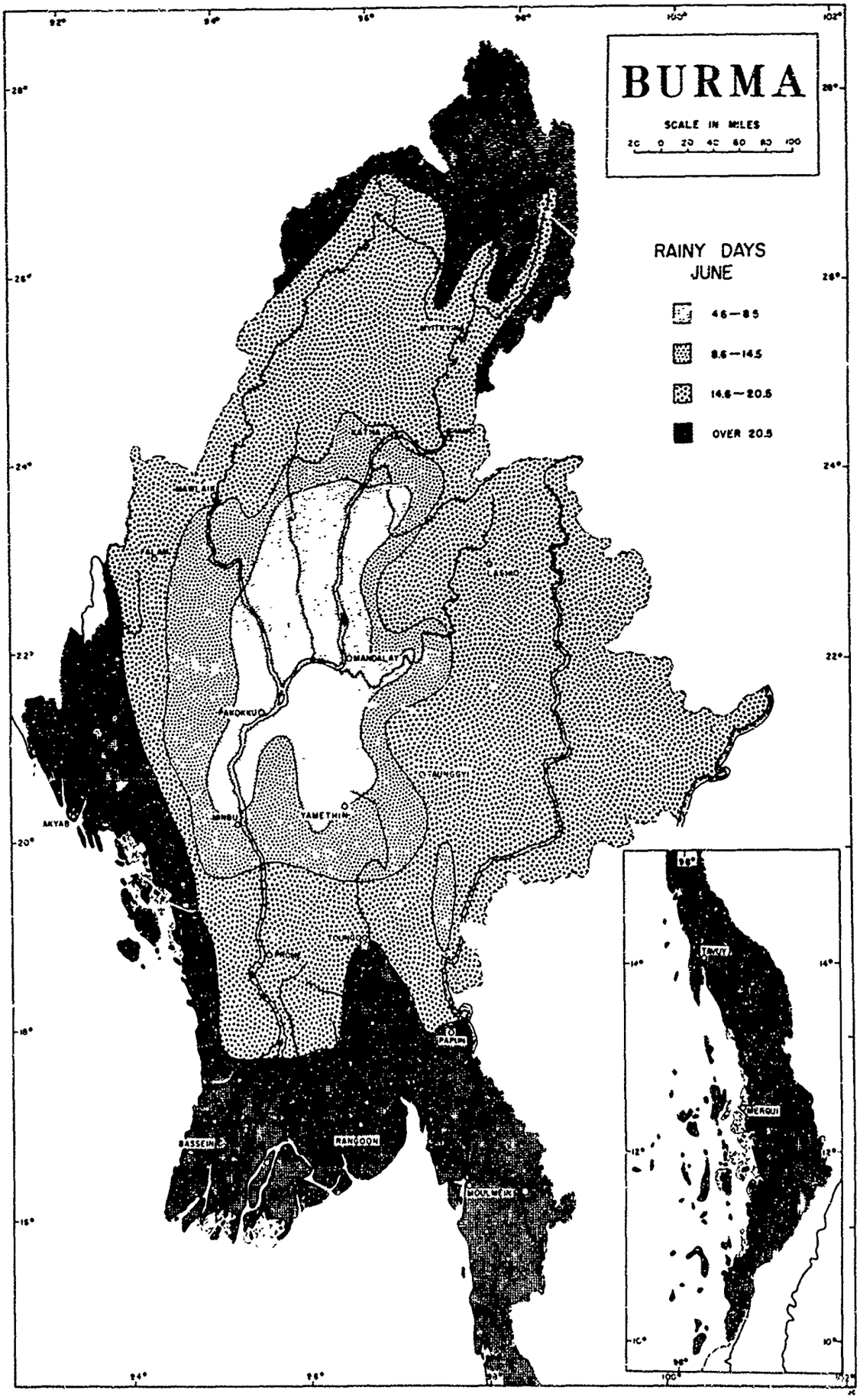
MAP 20


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINY DAYS
APRIL
0–1.0
1.1–2.5
2.6–4.5
4.6–8.5
8.5–14.5
MYITKYINA
KATHA
BHAMO
MAWLAIK
FALAM
LASHIO
OMANDALAY
PAKOKKU
AKYAB
MINBU
YAMETHIN
TAUNGGYI
TOUNGOO
PROME
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI
92°
94°
96°
98°
100°
102°
28°
26°
24°
22°
20°
18°
16°
14°
12°
10°

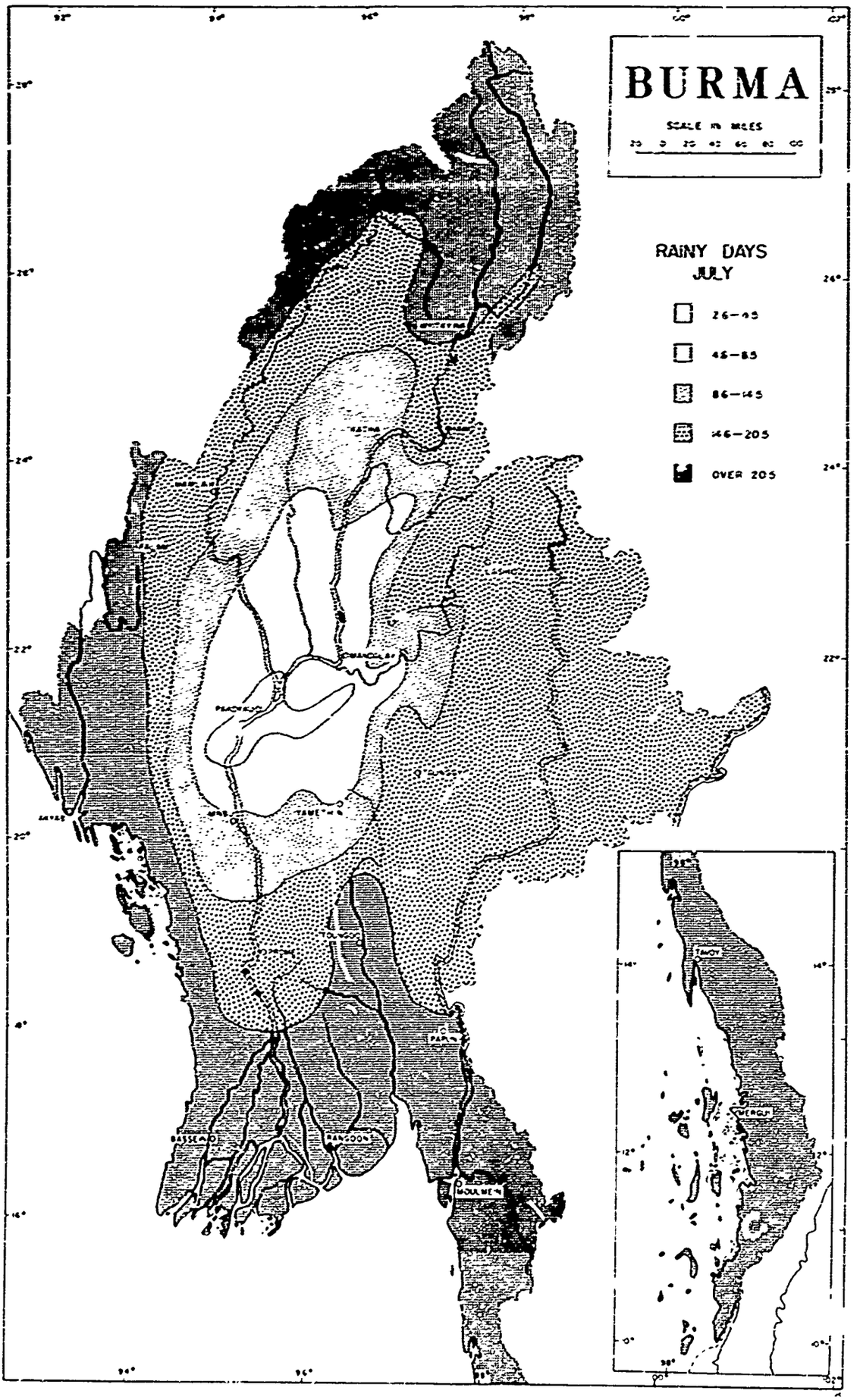
MAP 21


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINY DAYS
MAY
4·6–8·5
8·6–14·5
14·6–20·5
MYITKYINA
LASHIO
MANDALAY
PAKOKKU
AKYAB
MINBU
YAMETHIN
PROME
TOUNGOO
PAPUN
BASSEIN
RANGOON
MOULMEIN
MERGUI

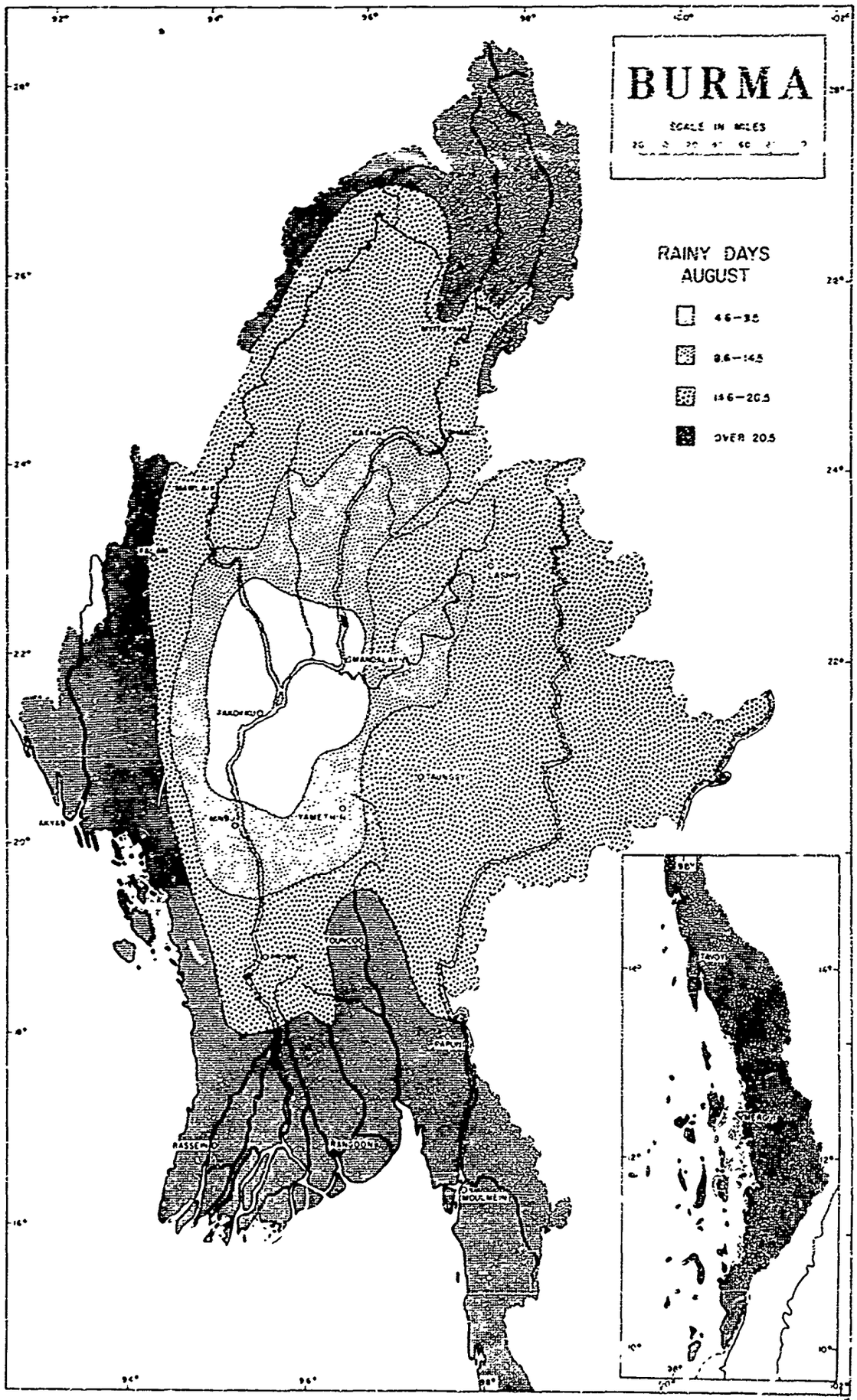
MAP 22


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINY DAYS
JUNE
4.6—8.5
8.6—14.5
14.6—20.5
OVER 20.5
MYITKYINA
KATHA
MANDALAY
LASHIO
AKYAB
YAMETHIN
TOUNGOO
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

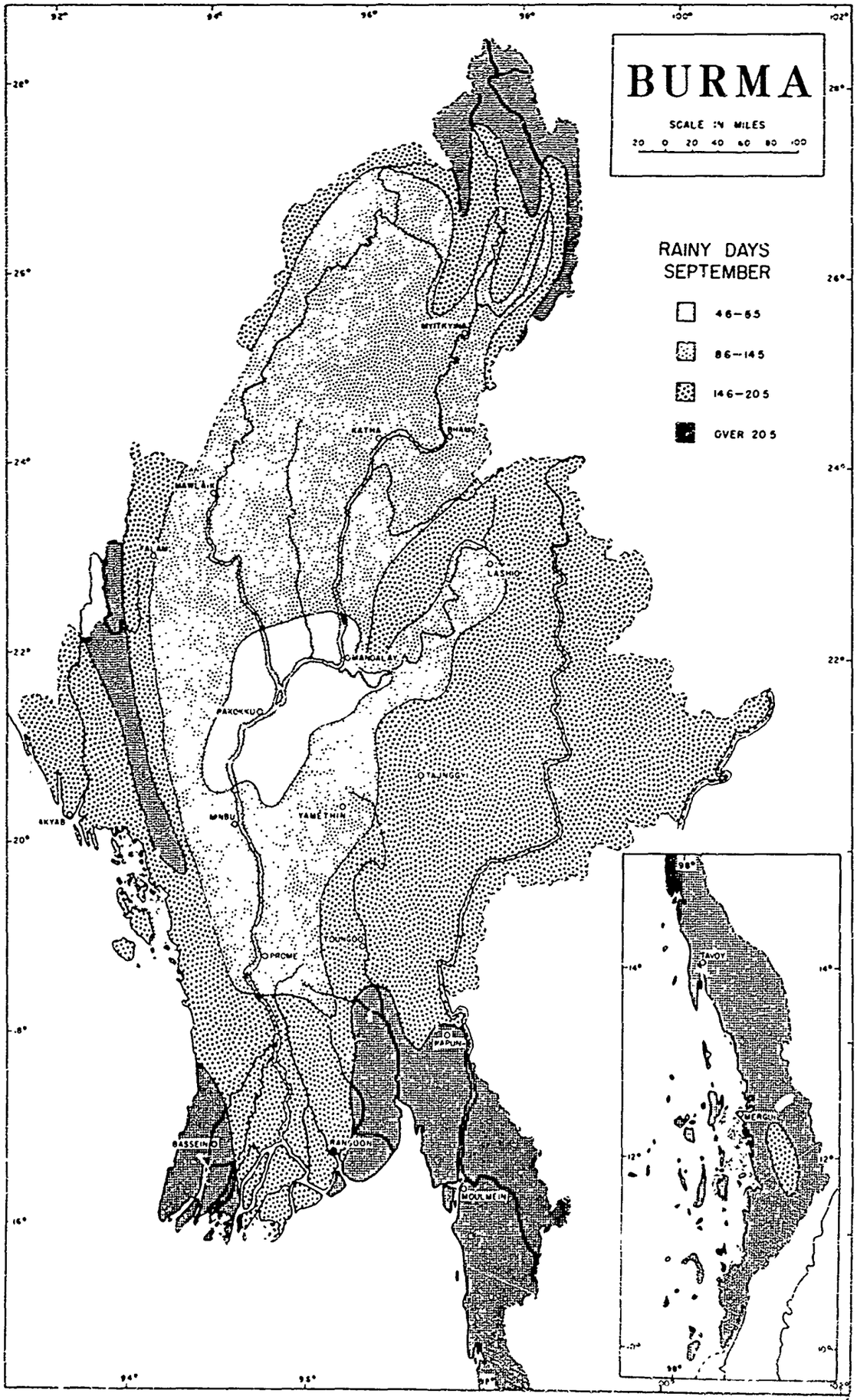
MAP 23


BURMA
SCALE IN MILES
RAINY DAYS
JULY
26–45
46–85
86–145
146–205
OVER 205
BASSEIN
RANGOON
MOULMEIN
AKYAB
MERGUI

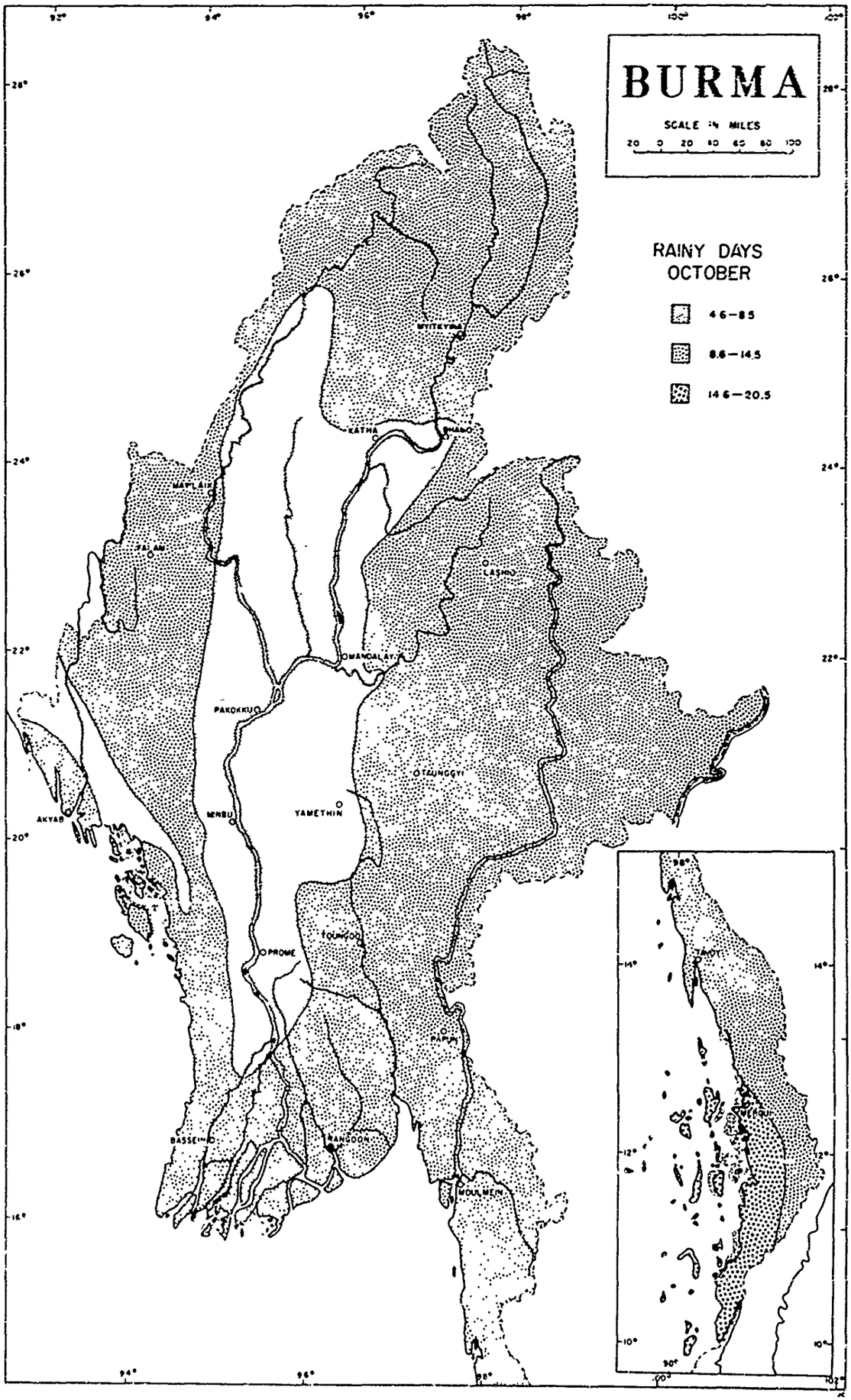
MAP 24


BURMA
SCALE IN MILES
RAINY DAYS
AUGUST
4·6–9·5
9·6–14·5
14·6–20·5
OVER 20·5

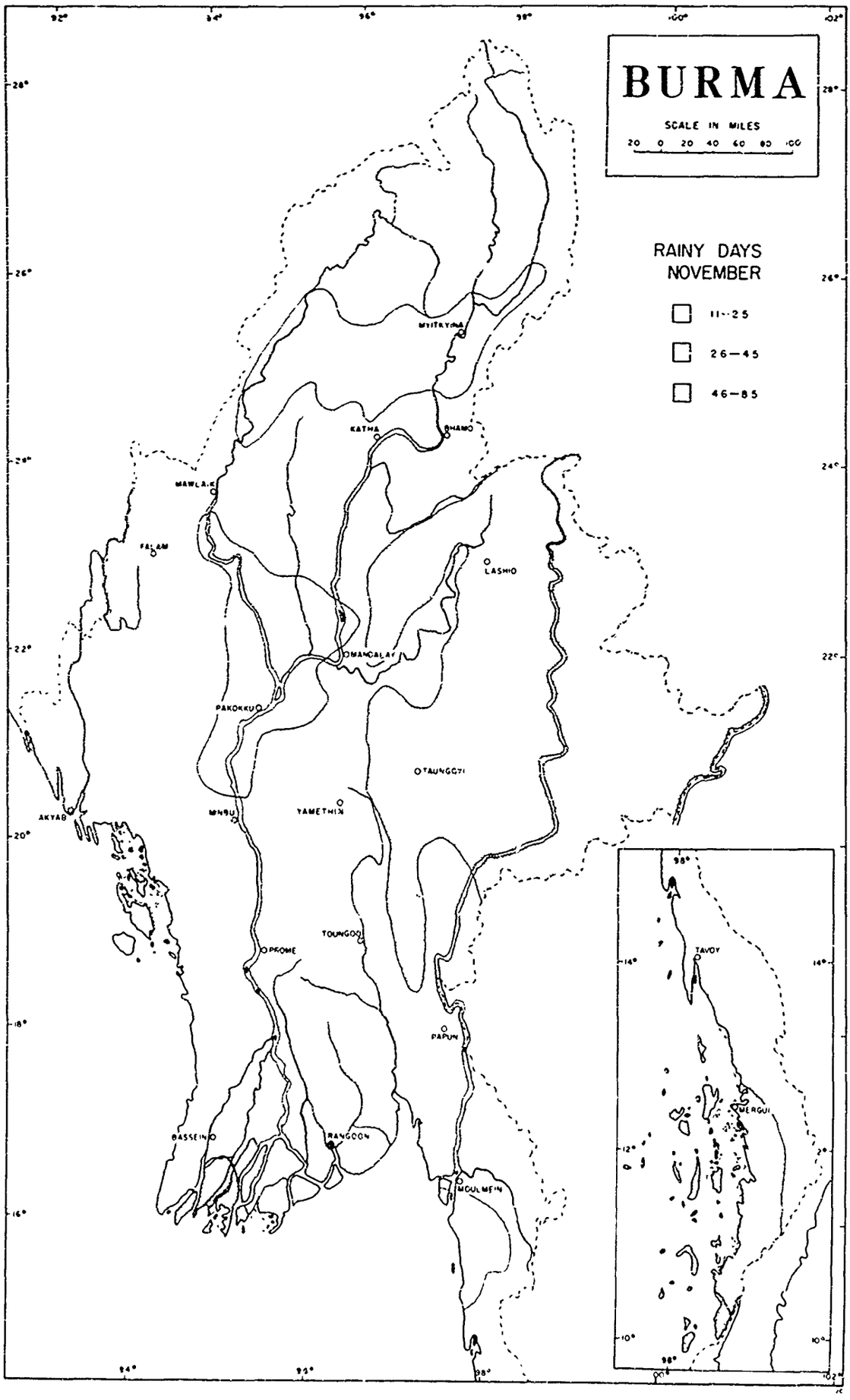
MAP 25


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINY DAYS
SEPTEMBER
46–65
86–145
146–205
OVER 205
MYITKYINA
KATHA
BHAMO
MAWLAIK
FALAM
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
YAMETHIN
MINBU
AKYAB
TOUNGOO
PROME
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

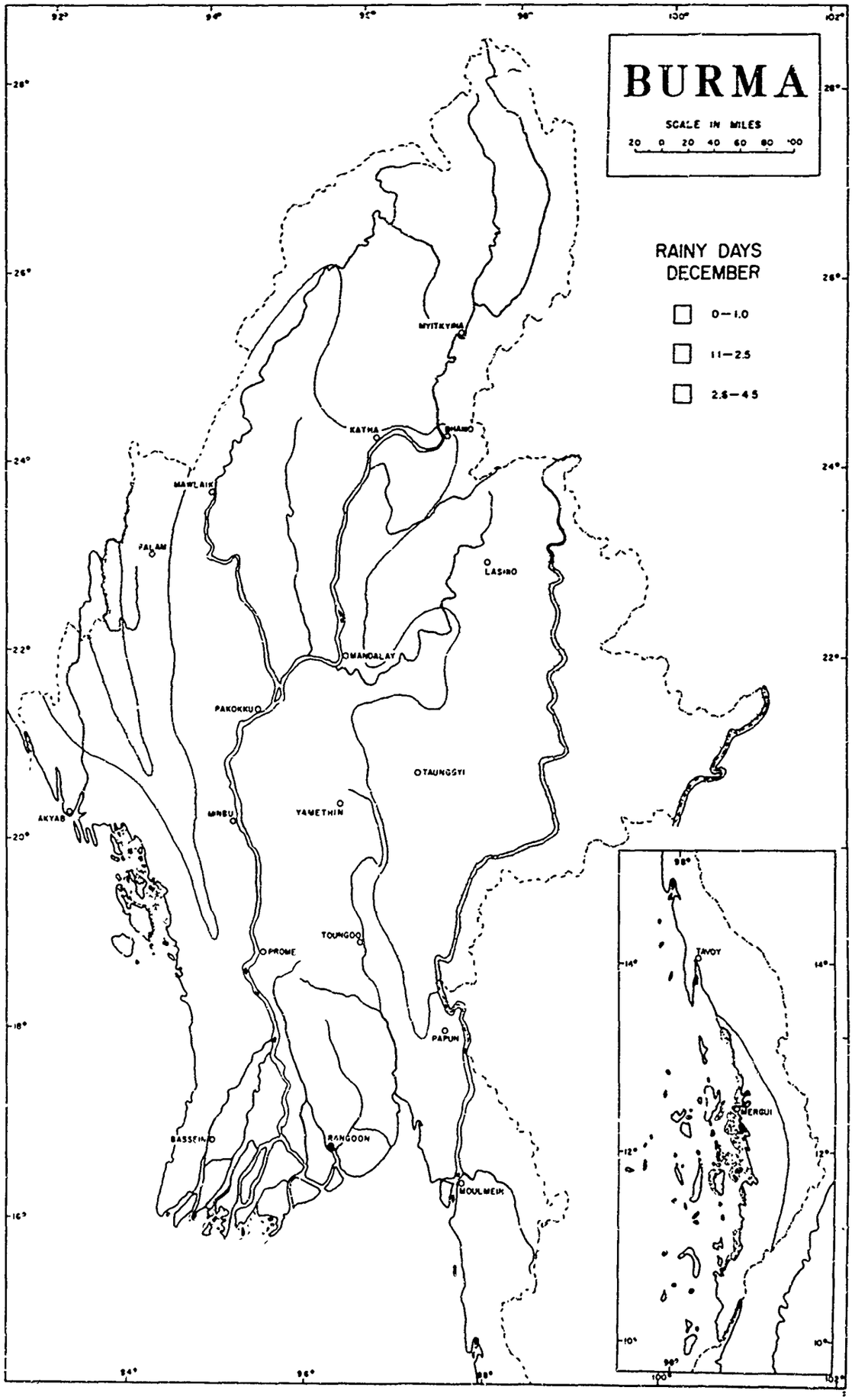
MAP 26


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINY DAYS
OCTOBER
4·6–8·5
8·6–14·5
14·6–20·5
MYITKYINA
KATHA
MANDALAY
PAKOKKU
YAMETHIN
MENBU
AKYAB
PROME
TOUNGOO
PAPUN
BASSEIN
RANGOON
MOULMEIN
LASHIO
TAVOY
MERGUI

MAP 27


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINY DAYS
NOVEMBER
11--25
26—45
46—85
MYITKYINA
KATHA
BHAMO
MAWLAIK
FALAM
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
AKYAB
MINBU
YAMETHIN
PROME
TOUNGOO
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

MAP 28


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
RAINY DAYS
DECEMBER
0—1.0
1.1—2.5
2.6—4.5
MYITKYINA
KATHA
BHAMO
MAWLAIK
PALAM
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
AKYAB
MRBU
YAMETHIN
PROME
TOUNGOO
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

MAP 29

PATTERN OF HEAVY RAINFALL

Map 30 showing "normal" number of days per year with five inches or more of rainfall was compiled from the records of 158 stations over a thirty year period. For seventy of the stations data were available for the full sequence of 30 years while the remaining stations had shorter records. The total data available for plotting the map amounted to a little over 3300 station years or an average of slightly over 20 years of record for each station.

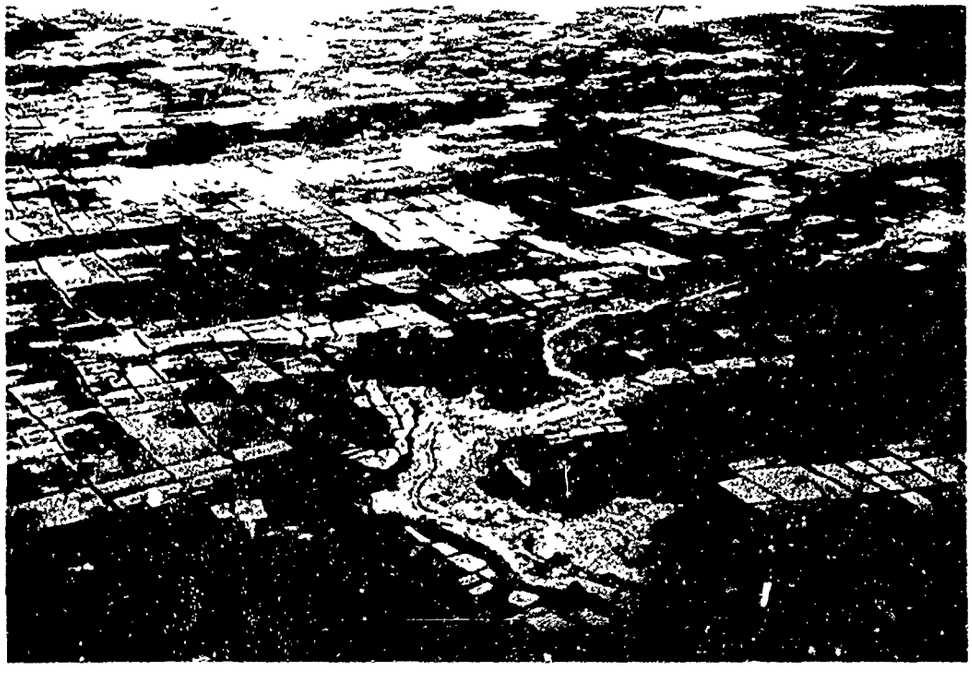
Very heavy rainfall is most frequent along the Arakan Coast and along the Tenasserim Coast from Tavoy to Moulmein. At Akyab during the 30 year period 1891-1920 daily rainfall totaled between five and ten inches on 214 separate occasions and on 15 of these days rainfall totaled over 10 inches. Its average of 7.53 occurrences per year of rainfall greater than five inches is the highest recorded by any station within the country. Sandoway and Taungup, 150 miles southeast of Akyab, each showed about 6.5 days of such heavy rain per year.

Several stations on the Tenasserim Coast recorded 4 and 5 and even 5.5 occurrences of 5 inch rainfall days per year, but no station in this area could equal the Arakan stations.

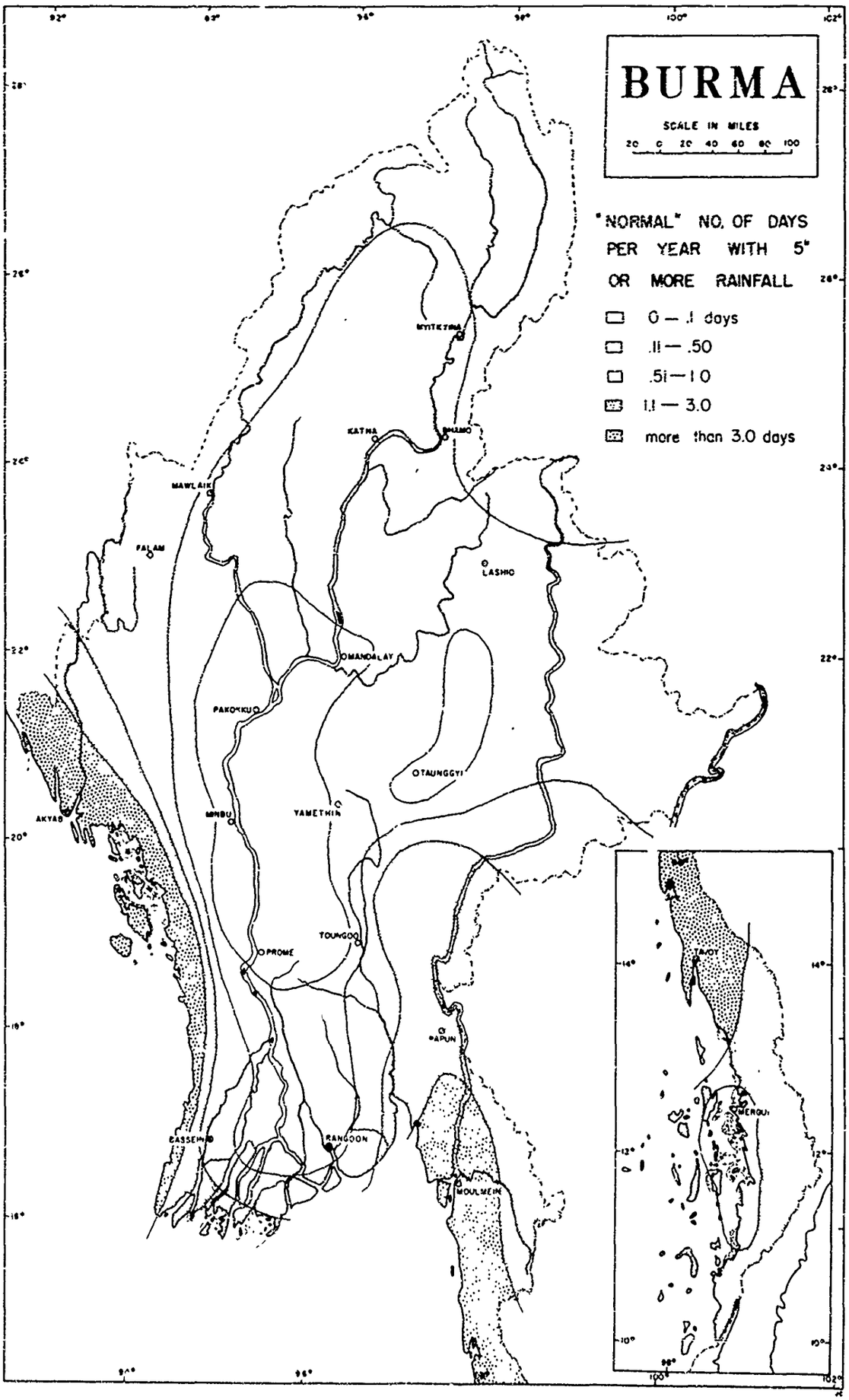
The frequency of heavy rainfall decreases rapidly inland from the fringes of the Irrawaddy Delta. The area least likely to experience very heavy rainfall appears to be the southern end of the Dry Belt. Thayetmyo District, in the Irrawaddy Valley between Prome and Minbu, had a total of five reporting raingauges. Four of these reported for all 30 years and the fifth reported for 22 years. In a total of 142 station years in this district only one station ever recorded as much as five inches of rainfall a day and this occurred only once.

To the north of Thayetmyo but still within the Dry Belt Minbu, Pakokku and Mandalay Districts all had remarkably low totals but all were higher than Thayetmyo. In these districts heavy rainfall occurred approximately one day in every eleven years at each station.

A second area of remarkably low occurrence of 5 inch rainfall days was found in the Shan State in a broad arc extending north and east from Taunggyi. Six stations in this area had records extending from eleven to seventeen years. Three of these stations reported single occurrences of heavy rainfall during the period of their records and three never did measure one day falls totaling as much as five inches.



Heavy rainfall over the Delta Regions often results in extensive flooding and the isolation of hundreds of tiny villages and many larger towns.


BURMA
SCALE IN MILES
20 0 20 40 60 80 100
"NORMAL" NO. OF DAYS PER YEAR WITH 5" OR MORE RAINFALL
0 — .1 days
.11 — .50
.51 — 1.0
1.1 — 3.0
more than 3.0 days
MYITKYINA
KATHA
BHAMO
MAWLAIK
FALAM
LASHIO
MANDALAY
PAKOKKU
TAUNGGYI
YAMETHIN
MINBU
AKYAB
TOUNGOO
PROME
PAPUN
BASSEIN
RANGOON
MOULMEIN
TAVOY
MERGUI

MAP 30

Table 5.

Rainfall Extremes [1].

	Average	Max.	(year)	Min.	(year)	Years of Record
Akyab	202.84	323.58	(1918)	120.62	(1957)	60 years
Kyaukpyu	185.93	221.78	(1926)	118.32	(1957)	30 "
Sandoway	214.05	272.95	(1918)	169.32	(1912)	74 "
Mawlaik	72.89	93.03	(1938)	32.44	(1925)	30 "
Monywa	31.32	45.51	(1947)	18.14	(1920)	35 "
Bhamo	73.08	97.54	(1910)	55.59	(1930)	55 "
Katha	59.71	79.35	(1938)	36.31	(1920)	53 "
Lashio	61.86	94.23	(1927)	42.10	(1957)	45 "
Mandalay	34.31	47.07	(1904)	19.40	(1924)	50 "
Maymyo	60.61	80.38	(1951)	40.99	(1931)	40 "
Myitkyina	84.41	109.58	(1905)	50.53	(1909)	45 "
Bassein	109.01	142.77	(1950)	73.54	(1906)	60 "
Maubin	95.69	121.46	(1919)	60.25	(1906)	62 "
Meiktila	35.36	55.37	(1926)	22.05	(1952)	51 "
Minbu	34.87	55.35	(1938)	23.14	(1931)	45 "
Myingyan	27.42	44.74	(1926)	11.40	(1957)	54 "
Pakokku	24.30	39.24	(1908)	13.37	(1921)	52 "
Prome	47.49	65.90	(1952)	32.48	(1919)	71 "
Pyapon	100.68	146.01	(1929)	75.02	(1918)	50 "
Loikaw	46.05	76.21	(1936)	32.08	(1931)	35 "
Taunggyi	66.62	91.15	(190[illegible]	47.76	(1931)	38 "
Thaton	217.01	252.72	(1923)	163.85	(1957)	50 "
Pegu	129.86	156.82	(1937)	82.10	(1957)	50 "
Pyinmana	55.13	76.83	(1927)	41.18	(1919)	54 "
Rangoon	103.07	125.99	(1950)	76.38	(1951)	60 "
Tharrawaddy	87.11	114.99	(1914)	61.27	(1957)	40 "
Toungoo	83.21	111.67	(1907)	53.42	(1957)	60 "
Yamethin	38.16	59.90	(1916)	18.60	(1958)	45 "
Mergui	162.28	190.68	(1901)	126.22	(1958)	60 "
Moulmein	190.09	241.08	(1925)	140.45	(1927)	60 "
Tavoy	214.85	285.25	(1904)	175.04	(1958)	50 "
Victoria Point	165.62	191.51	(1917)	120.86	(1947)	30 "

1. Compiled from: Hydrological Division, Burma Meteorological Department, **Hydrologic Summary for 1958**, Gov. of Burma, Rangoon, 1960. mimeo, pp. 2-1 through 2-34.

Table 5a.

"Normal" Rainfall at Selected Stations
Burma
in Inches by Months[1]

Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Akyab	0.06	0.15	0.49	2.07	13.95	46.94	54.80	45.19	22.57	10.91	5.48	0.76	203.37
Sandoway	0.09	0.09	0.24	1.35	13.51	48.71	62.76	49.65	24.72	6.93	2.82	0.41	211.66
Prome	0.03	0.07	0.14	0.77	5.48	8.78	9.02	8.96	7.21	4.49	1.70	0.24	46.89
Pegu	0.23	0.43	0.43	1.10	13.16	23.25	29.55	29.60	19.76	7.40	2.13	0.33	127.37
Bassein	0.12	0.28	0.17	1.06	9.84	23.02	24.55	23.07	15.20	8.19	3.24	0.40	109.14
Wakema	0.07	0.19	0.21	0.78	11.31	18.25	20.07	19.38	13.52	6.65	3.00	1.17	94.60
Pyapon	0.09	0.21	0.36	1.00	11.13	19.35	19.91	19.10	13.27	7.16	3.59	0.88	96.05
Tavoy	0.20	0.44	1.59	2.63	22.71	44.24	49.22	47.33	33.06	10.66	2.30	0.36	214.74
Mergui	0.90	2.02	3.12	5.28	16.93	29.41	31.45	29.21	26.43	12.09	3.71	0.69	161.24
Victoria Point	0.40	0.75	2.44	4.82	19.74	29.69	30.05	26.18	26.22	17.79	6.36	2.02	166.46
Minbu	0.04	0.06	0.29	0.77	5.64	5.75	4.52	5.27	6.20	4.51	1.82	0.51	35.38
Pakokku	0.00	0.06	0.19	0.48	3.11	3.70	2.02	4.48	4.78	3.75	1.13	0.21	23.91
Kyaukse	0.09	0.09	0.25	1.16	5.02	3.91	2.32	4.02	5.94	4.47	2.22	0.35	29.84
Myingyan	0.02	0.05	0.18	0.42	3.76	3.43	3.05	4.50	5.86	3.69	1.23	0.26	26.45
Pyinmana	0.07	0.14	0.30	1.29	6.64	8.20	9.67	11.67	8.46	5.85	2.16	0.30	54.75
Shwebo	0.05	0.08	0.18	0.89	4.75	5.82	4.07	5.81	6.53	3.98	1.40	0.29	32.80
Mawlaik	0.05	0.37	0.12	1.52	10.65	10.94	11.91	12.27	14.11	8.85	2.22	0.32	73.33
Bhamo	0.49	0.48	0.75	1.89	6.14	13.88	16.78	15.38	9.89	4.26	1.50	0.57	72.01
Myitkyina	0.41	0.85	0.94	1.96	6.06	15.13	19.17	16.37	9.68	6.83	1.17	0.42	79.59
Putao	0.80	1.74	2.84	5.19	7.01	26.68	35.12	37.73	27.52	7.11	1.93	0.31	154.07
Kalaw	0.11	0.07	0.69	2.53	8.48	6.90	6.90	8.17	7.50	6.47	3.73	0.83	52.31
Lashio	0.27	0.30	0.59	2.18	6.91	6.97	12.00	12.70	7.84	5.73	2.75	0.86	61.87
Falam	0.14	0.49	1.14	3.05	5.52	12.78	11.81	12.09	9.32	6.90	1.91	0.63	65.82

1. Compiled from: Burma Meteorological Department, **Statement Showing the Monthly and Annual Rainfall at Rain-Recording Stations in Burma for the Year 1954**, Gov. of Burma, Rangoon, 1955. It will be noted that "normal" as recorded in this table often differs slightly from the average reported in table 5.

Date of Heaviest Rainfall

Heaviest rain of the year is most likely to occur sometime during the months of July, August or September. The onset of the monsoon period is normally marked by intermittent periods of rainy days and dry days. During the early phases of the monsoon, rainfall is likely to occur as moderately heavy to heavy showers of anywhere from 15 minutes to one hour duration interspersed with drizzle and short periods of sunshine. Very often this early phase of the monsoon is followed by several days of clear dry weather which in turn is followed by very heavy rains, often including the heaviest of the year. An analysis of daily rainfall records covering 134 station years shows that the median date for the years highest 24 hour rainfall total is July 7. This date, however, is extremely variable both from year to year and from region to region.

One thing that is certain is that the maximum 24 hour rainfall occurs between mid-April and mid-November. Of the 134 station years for which daily records have been studied only two annual maximums occurred in April and seven in November. Sixty-five percent of the records are almost equally divided between July, August or September while May holds the fourth greatest number with 18 percent followed by June with 15 percent. A study of 24 additional stations for which the data is summarized by months and with records varying from 9 to 65 years, a total of 944 station years, indicates much the same pattern. No absolute daily maximum for the year was recorded during the months of December-March. One of these 24 stations shows an absolute maximum in April, and one in Novem-

Heaviest rainfall of the year is most likely to occur during the months of July, August or September and often results from violent convectional activity. Here on the Shan Upland clouds from a heavy thunder shower form the backdrop of a typical farm view. Notice that the heavy rains have caused considerable erosion along the road.

ber; two show absolute maximums in October and two in September. The remaining 18 stations have recorded absolute maximum falls in May, June, July or August with August and May in that order the most important.

The 11 year median volume of maximum 24 hour precipitation also shows considerable variation from place to place. As might be expected Akyab on the Arakan Coast records the highest median value, 7.5 inches. Mergui, also at a coastal location at the foot of the mountains but far to the south of Akyab, is well behind in second place but nevertheless reports a respectable 4.7 inch median for annual 24 hour maximum rainfall. Inland from Rangoon values drop rapidly to reach a minimum near the southern edge of the Dry Belt and then appear to rise again as one continues north. Thus Rangoon's median maximum is 4.1 inches while at Prome the figure is only 2.0 inches and at Pakokku and Mandalay respectively the medians are 2.7 and 3.8 inches. The reason for an increase in the median inland from the border of the Dry Belt is apparently related to the fact that at coastal stations such as Akyab and Mergui rainfall is caused chiefly by weak cyclonic disturbances traveling with the monsoon air drift and by orographic cooling along the mountains — thus heavy rains. In stations from Rangoon north through the Dry Belt orographic cooling is minimal. At Rangoon and at Prome the major cause of heavy precipitation appears to be the passage of the weak lows. As these move further and further from the sea the volume of rain produced becomes smaller. However in the Dry Belt with its much greater incindence of sunlight and its higher temperatures, convectional activity is far better developed. Thunderstorms are both more frequent and more intense at Pakokku and Mandalay than they are at Rangoon or at Prome. These storms, although of small areal extent and thus infrequent over any given station, often cause intense rainfall for short periods and probably account for the higher 24 hour rainfall records in the Dry Belt than are found at stations such as Prome, Toungoo, Thayetmyo and Pyinmana at the edge of the Dry Belt.

"BURSTING" OF THE MONSOON

Popular literature often leads one to believe that the monsoon "bursts with full fury" upon the Burmese landscape at a given date near the end of May. Such a statement may well be true for almost any given station in any single year, but such a statement is inadequate, strongly misleading and vastly oversimplified.

In describing the monsoon season as it exists over the Ganges and Irrawaddy Deltas, W. G. Moore's **A Dictionary of Geography,** says in part: "The southwest monsoon moves forward with a definite front and arrives at each place at approximately the same date each year; the first rain is known as the 'burst of the monsoon' ".

A study of the available data for several stations in Burma indicates that this statement is wrong in two respects. At most stations there is considerable variation in the date of the onset of the monsoon rains and also the first rain is normally considerably less than the average fall per day for the entire season. The data would thus indicate that one is hardly justified in speaking of the "burst" of the monsoon.

To take two examples of stations in the most direct path of the heaviest monsoon influence, the data for Akyab and Rangoon prove enlightening. The first question is to decide just when the "monsoon rains" begin. As has been indicated and as may be observed from graphs 1 and 2 the beginning of the monsoon rains is marked by alternating, roughly equal periods of rainy days and dry days. Such conditions last for approximately two weeks and are followed by several months during which the typical pattern is to have a number of long periods of rainy days each followed by a short period of dry weather. For purposes of this study the monsoon period is defined as the season in which there are more rainy days than there are dry days. The break of the monsoon rains then is taken as the first rainy day of the first 20 day period, starting with January 1, during which at least eleven days recorded rainfall and no more than nine days were dry. Moreover a rainy day was defined as a day recording one one-hundredth of an inch or more of precipitation. This definition of a rainy day is the same definition used by the Meteorological Department of the Union of Burma and the data was derived from two sources: "Daily Rainfall of India, for the years prior to 1937 and "Daily Rainfall Recorded in Burma for the Month", for the years following 1937.

Using the above criterion and studying the daily rainfall data for eleven years it was found that at Rangoon the "normal" condition was for the monsoon rains to begin on May 6th, the mean date over the period. However during the eleven years under study the date of the onset of the rainy period varied from April 26 to May 21, a 25 day period. Also the mean variation of the beginning of the rains from the "normal" of May 6th was 7 days. The first day of the monsoon rains according to this definition brought an average of .36 inches of rainfall compared to typical fall for all rainy days for the year of .63 inches. Thus the advent of the rains varied considerably in date and brought only 60 percent as much rain as the average for all rainy days.

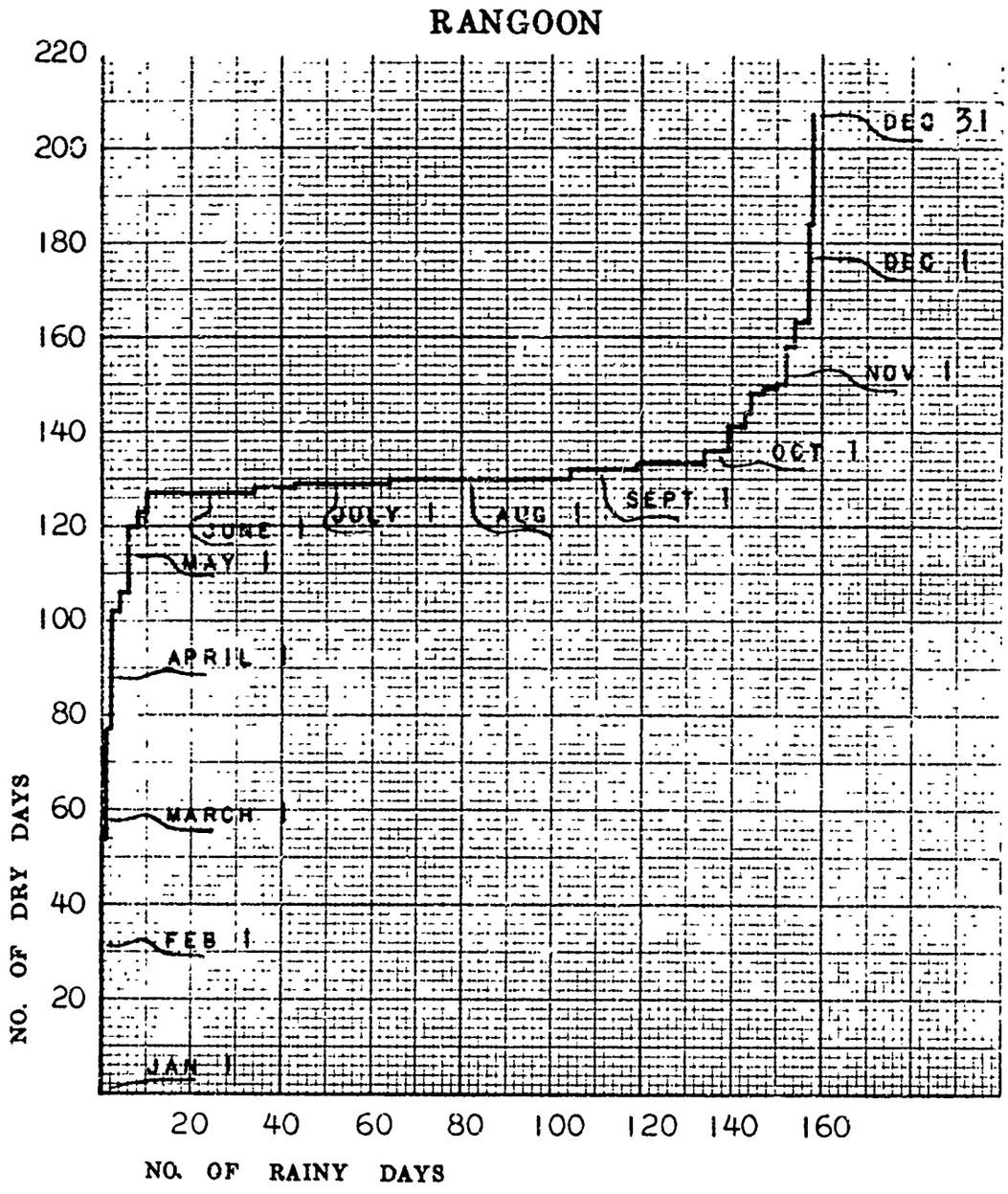
At Akyab on the Arakan Coast, an area experiencing the heaviest rainfall in Burma and the area with the most pronounced "monsoon" rainfall pattern, the story is similar. At Akyab the monsoon rains "normally" begin on May 9, three days later than at Rangoon and the variation in beginning date was from May 1 to June 7, a 37 day period or almost two weeks greater than at Rangoon. During one of the years under study the rains at Akyab were delayed a full four weeks beyond their expected arrival. If this year is omitted from the data it is found that the variation is confined between May 1 and May 20, and that the average variation from the May 9 "normal" date is only six days. The "bursting" of the monsoon rains at Akyab brought an average of .76 inches of rainfall, heavy by standards in many parts of the world, but less than 60 percent of the 1.39 inches which is the average fall per rainy day for the entire year at Akyab.

For the country as a whole the monsoon normally begins first in the southern section of the Tenasserim Coast. At Mergui, for example, the normal date appears to be about April 24. Roughly two weeks later the rains begin in earnest at Rangoon and along the Arakan Coast. Within five days of the Rangoon date the rains usually have begun at Papun in the Karen State, at Myitkyina in the mountainous Kachin State to the far north and in both the eastern highlands

During the last half of May the Irrawaddy Delta often experiences the first of the monsoon rains. The early rains are followed by several days of sunny weather with scattered clouds. At this time farmers move to the fields to complete the first phases of farm preparation.

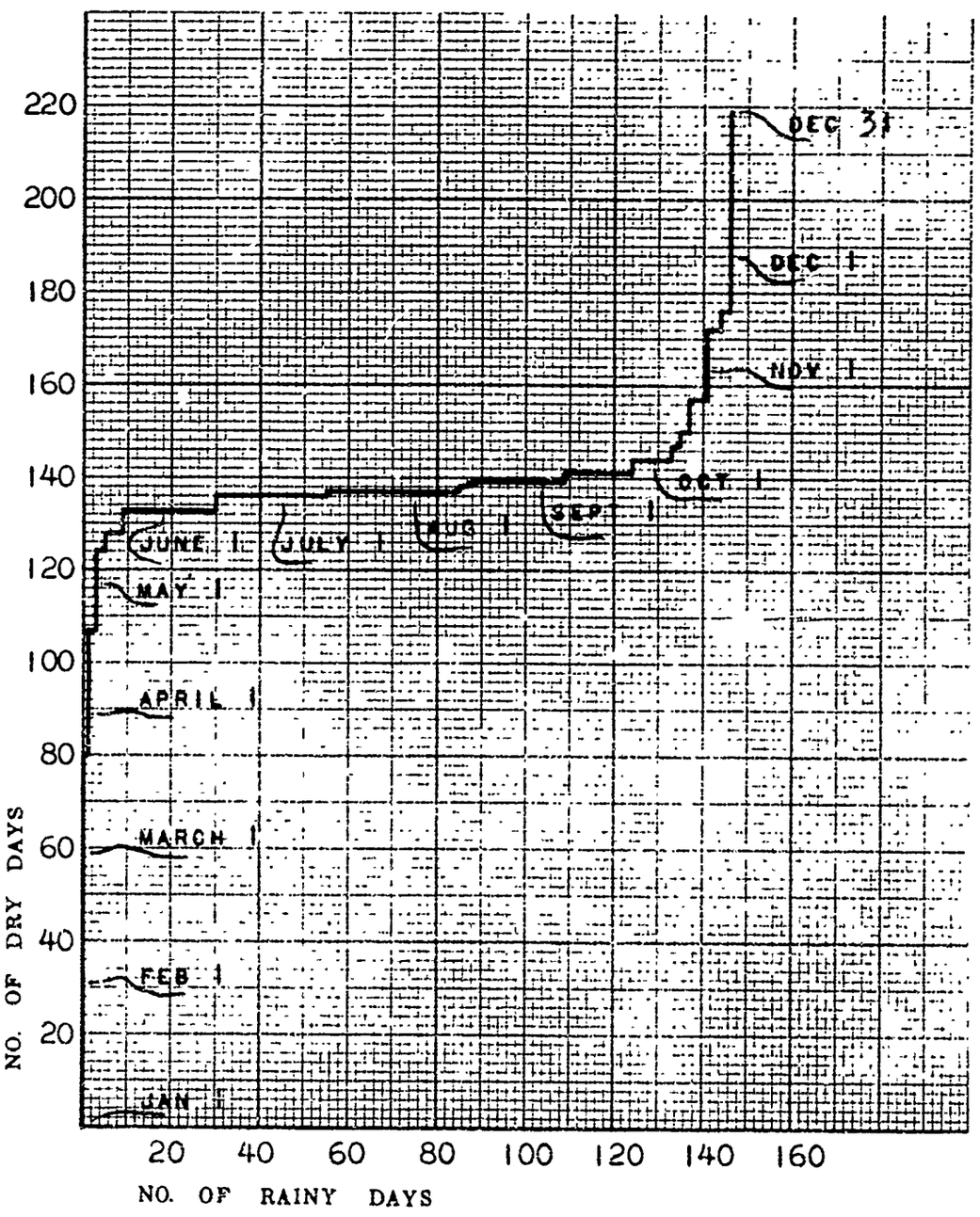
(Taunggyi) and the western highlands (Falam). About two weeks after the Rangoon date the rainy season at Prome. 150 miles inland, begins and ten days after that, or roughly the first of June, the wet season begins at Mandalay, 375 miles north of Rangoon. Two interesting features of this apparent northward movement of the rains from Rangoon to Prome to Mandalay, are obvious from the data. First; in no year for which data is at hand did the rains begin sooner at Prome than at Rangoon, although in 1930 they started on the same date at both stations. Second; during five of the eleven years under study the rains began at Mandalay before they began at Prome 225 miles to the south. It seems clear that, through Burma's Dry Belt at least, the monsoon rains do not move forward with a definite front.

In the very heart of the Dry Belt at Pakokku the normal date for the monsoon appears to be June 21st, a full six weeks later than at Rangoon. In fact, using the definition of 11 days with rain out of 20 consecutive days, certain Dry Belt stations such as Mandalay and Pakokku have true monsoon rains only five of every ten years. During the other years the number of rainy days at such stations is so low and the pattern of occurrence is so scattered that at no time during the year is rainfall recorded on as many as eleven out of twenty consecutive days.


RANGOON
220
200
180
160
140
120
100
80
60
40
20
NO. OF DRY DAYS
DEC 31
DEC 1
NOV 1
OCT 1
SEPT 1
AUG 1
JULY 1
JUNE 1
MAY 1
APRIL 1
MARCH 1
FEB 1
JAN 1
20
40
60
80
100
120
140
160
NO. OF RAINY DAYS

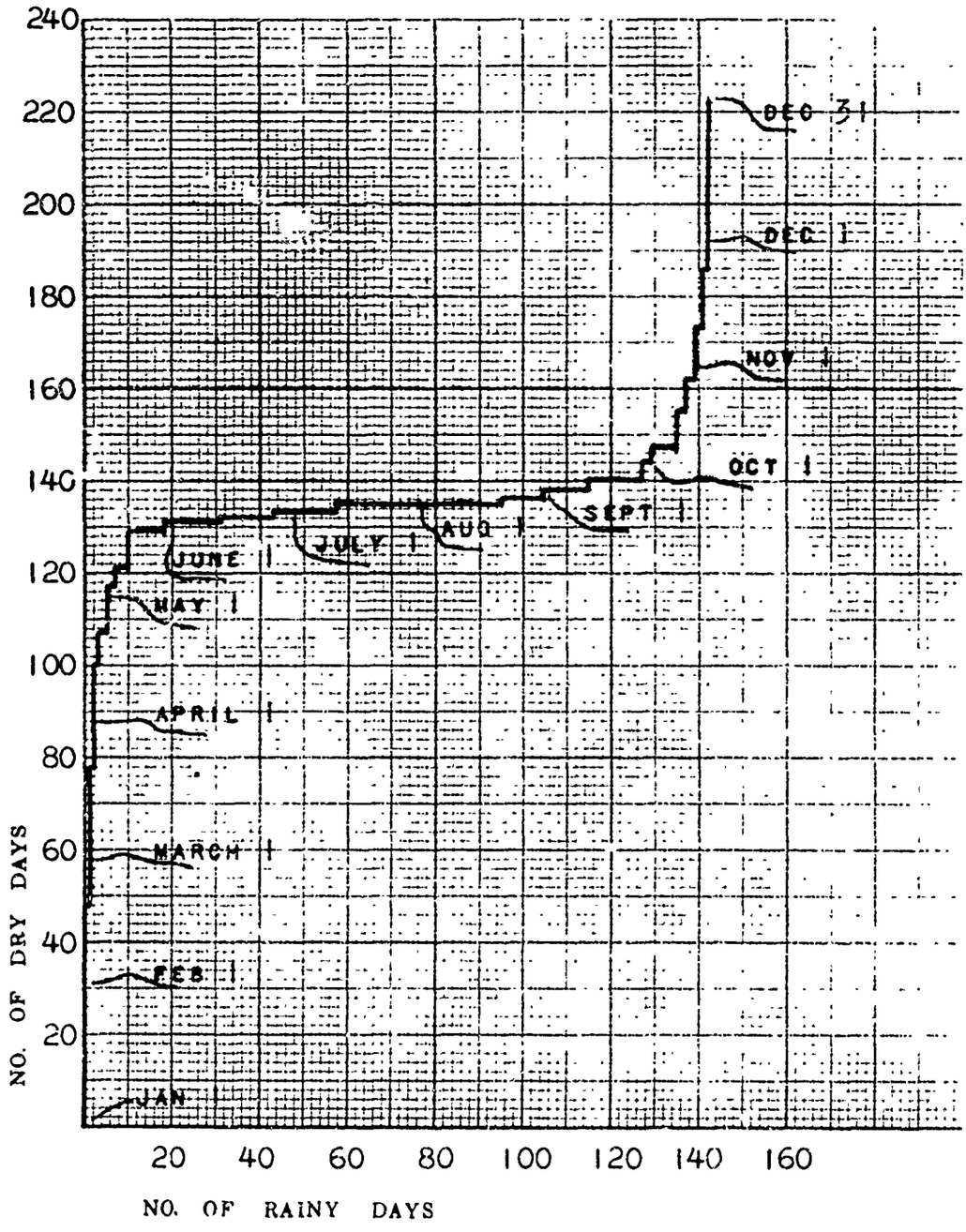
GRAPH 1

AKYAB



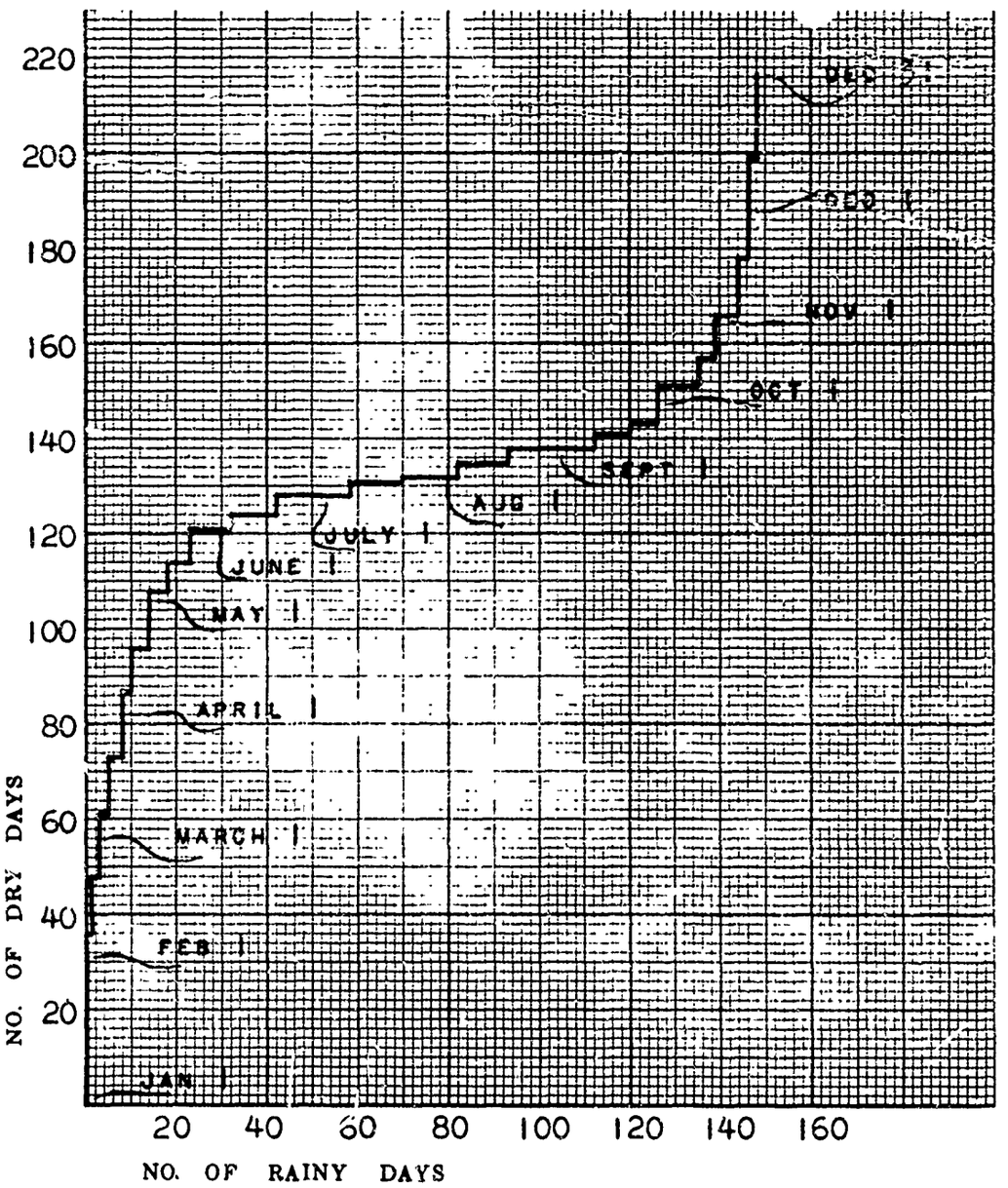
GRAPH 2

PAPUN



GRAPH 3

FALAM



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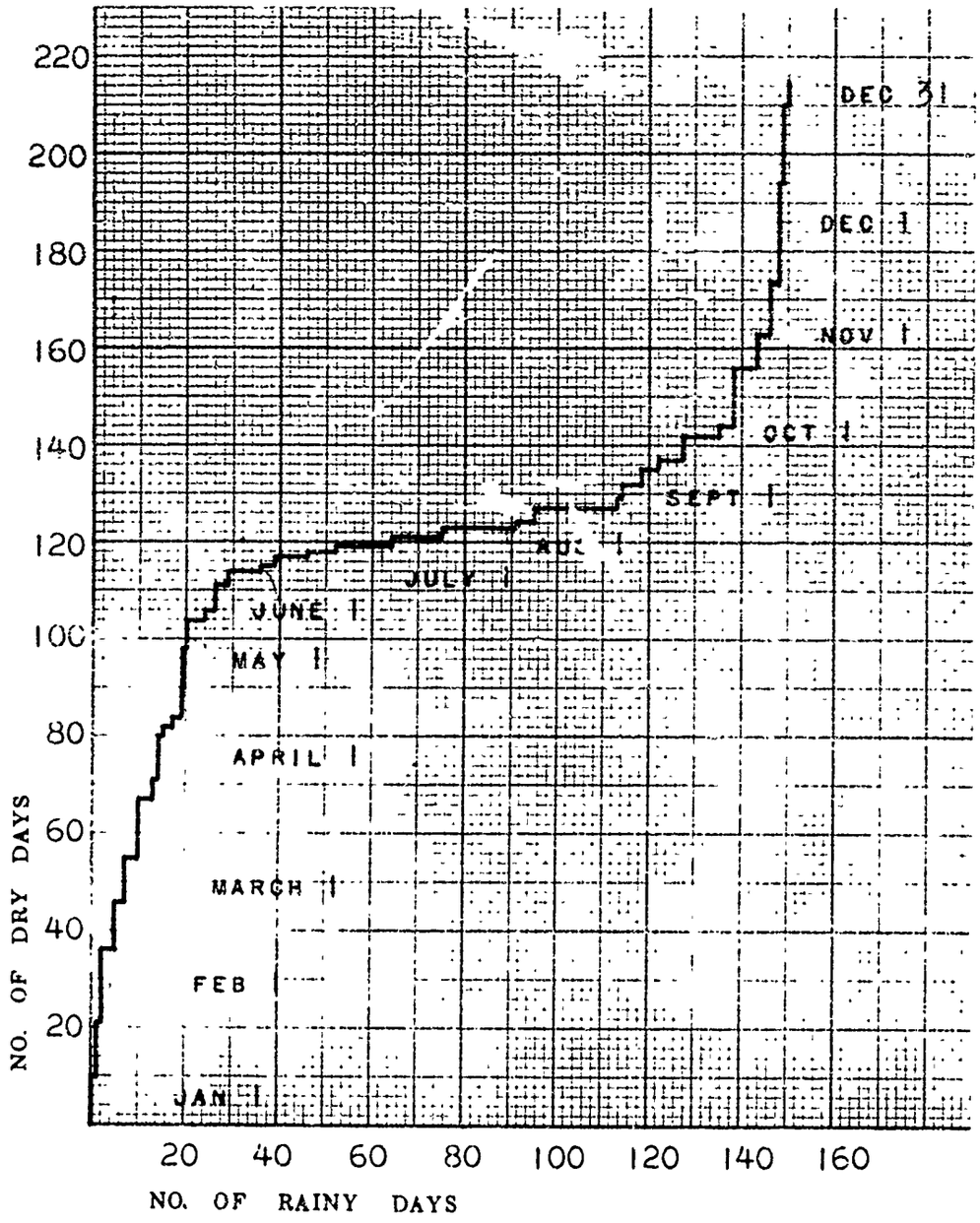
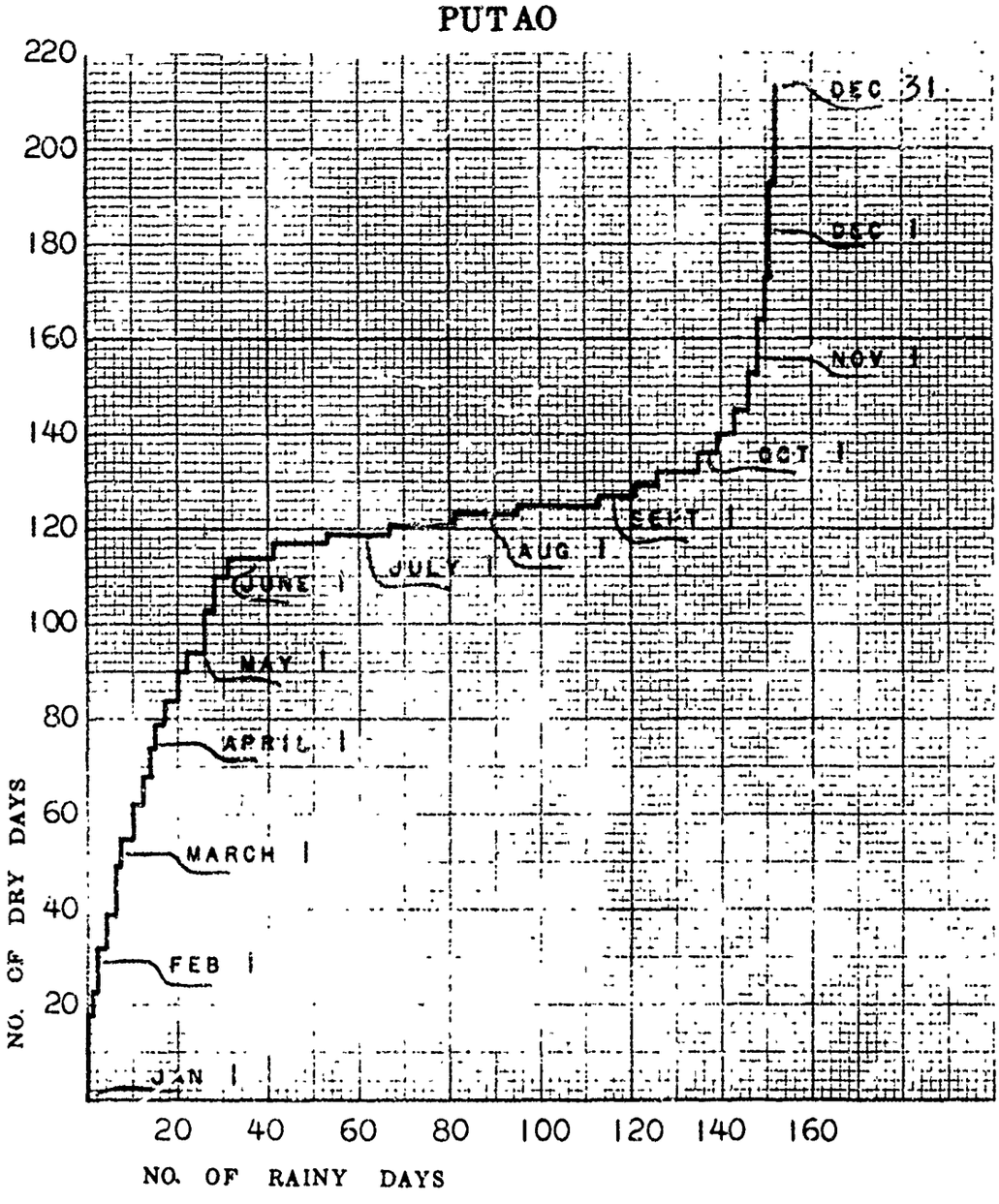
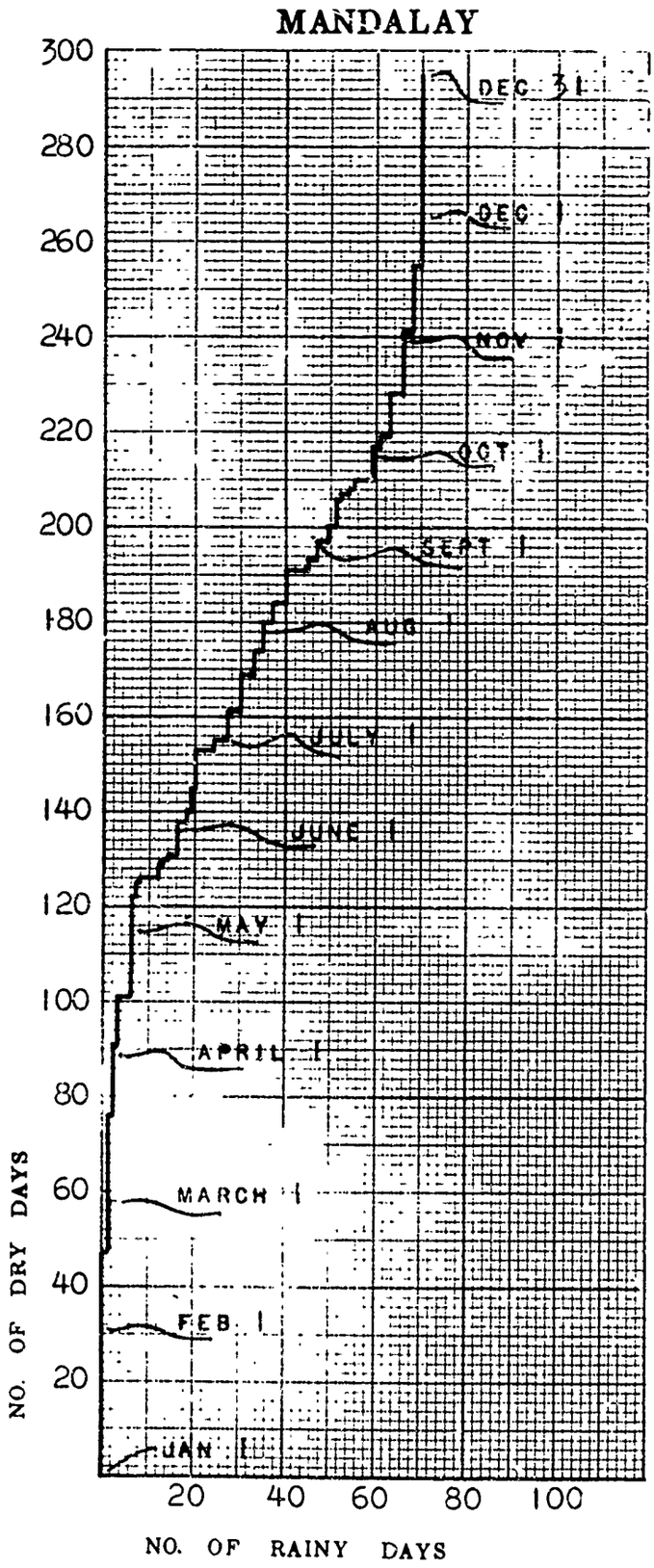
MYITKYINA



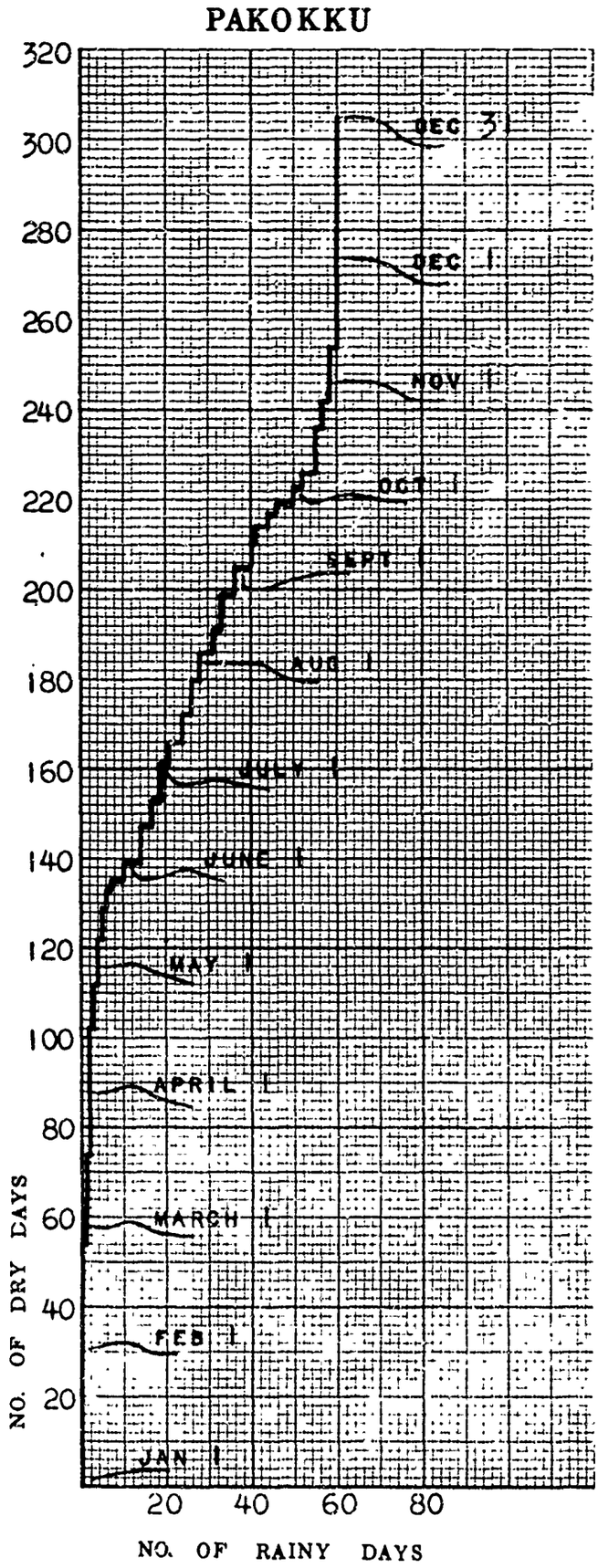
GRAPH 5


PUT AO
220
200
180
160
140
120
100
80
60
40
20
NO. OF DRY DAYS
DEC 31
DEC 1
NOV 1
OCT 1
SEPT 1
AUG 1
JULY 1
JUNE 1
MAY 1
APRIL 1
MARCH 1
FEB 1
JAN 1
20
40
60
80
100
120
140
160
NO. OF RAINY DAYS

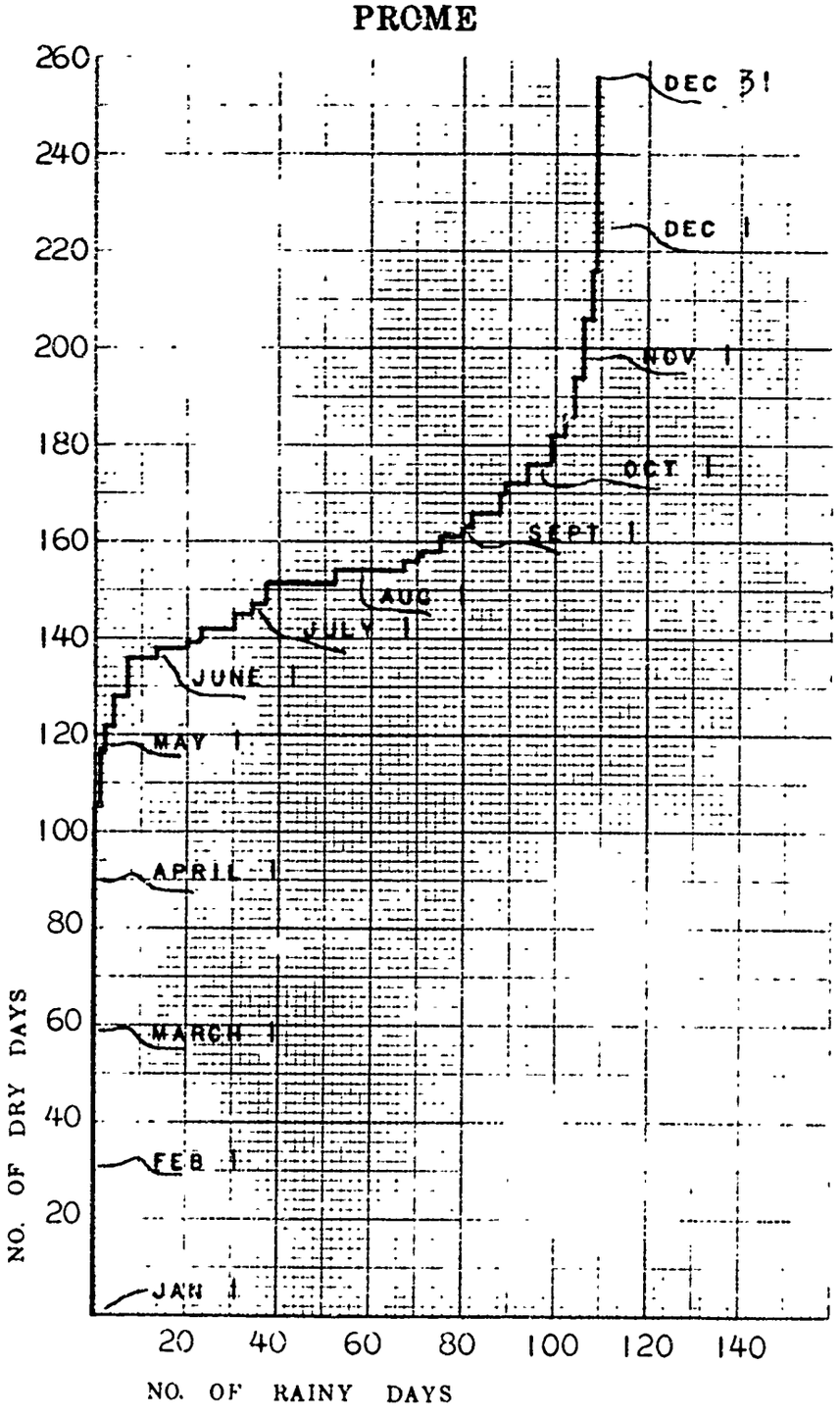
GRAPH 6


MANDALAY
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
DEC 31
DEC 1
NOV 1
OCT 1
SEPT 1
AUG 1
JULY 1
JUNE 1
MAY 1
APRIL 1
MARCH 1
FEB 1
JAN 1
NO. OF DRY DAYS
20
40
60
80
100
NO. OF RAINY DAYS

GRAPH 7

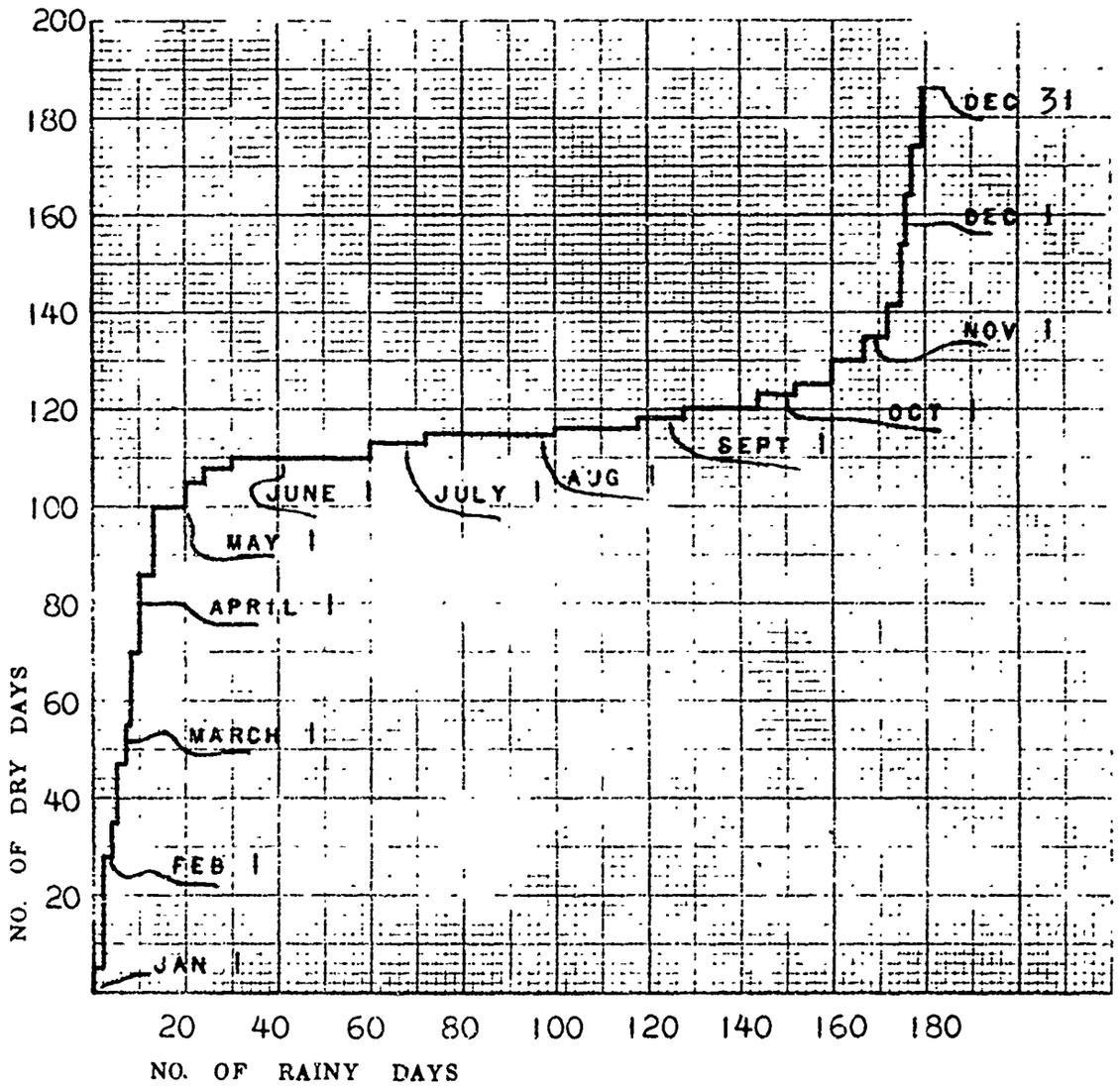

PAKOKKU
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
DEC 3
DEC 1
NOV 1
OCT 1
SEPT 1
AUG 1
JULY 1
JUNE 1
MAY 1
APRIL 1
MARCH 1
FEB 1
JAN 1
NO. OF DRY DAYS
20
40
60
80
NO. OF RAINY DAYS

GRAPH 8

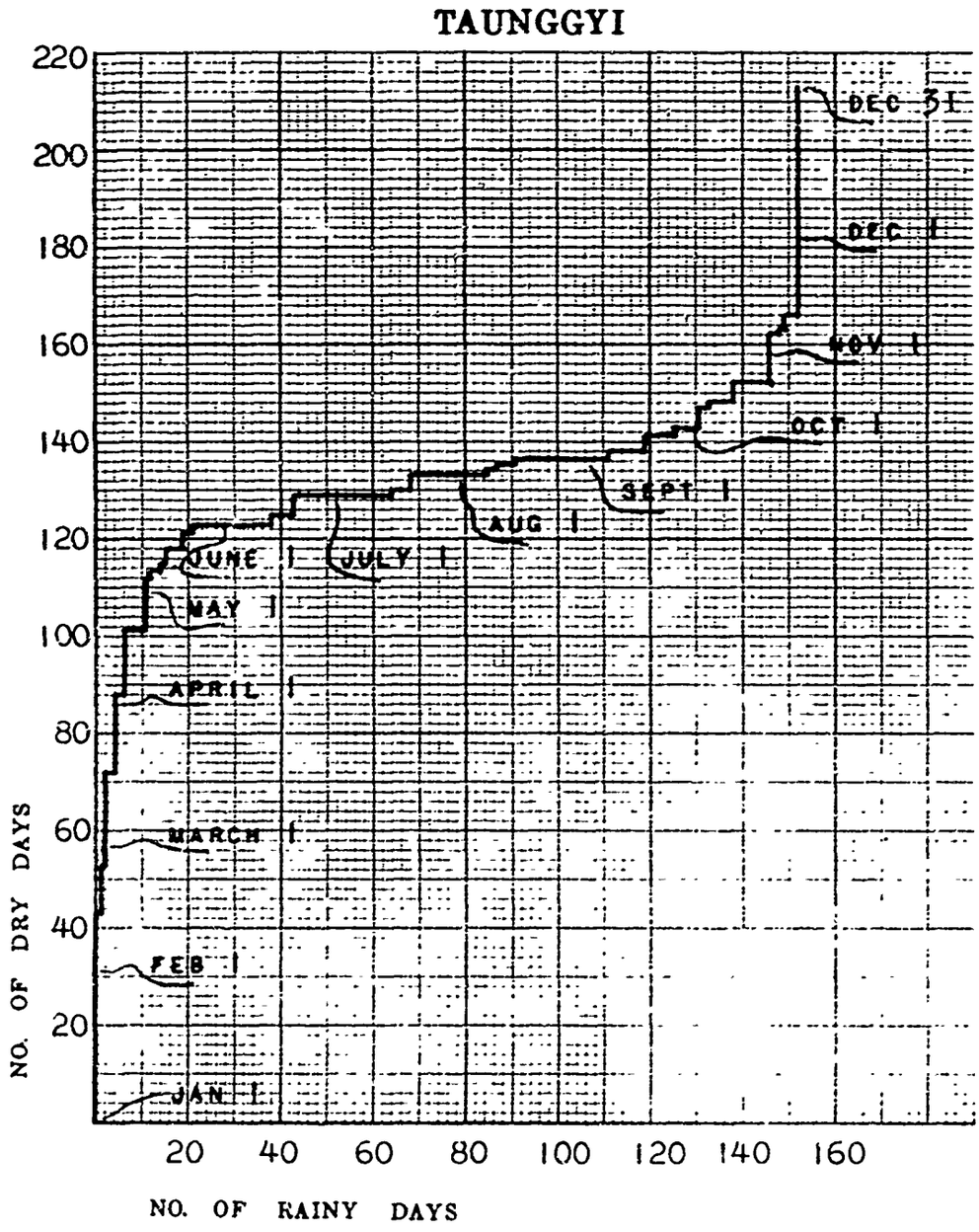

PROME
260
240
220
200
180
160
140
120
100
80
60
40
20
DEC 31
DEC 1
NOV 1
OCT 1
SEPT 1
AUG
JULY 1
JUNE 1
MAY 1
APRIL 1
MARCH 1
FEB 1
JAN 1
NO. OF DRY DAYS
20
40
60
80
100
120
140
NO. OF RAINY DAYS

GRAPH 9

MERGUI



GRAPH 10


TAUNGGYI
220
200
180
160
140
120
100
80
60
40
20
NO. OF DRY DAYS
DEC 31
DEC 1
NOV 1
OCT 1
SEPT 1
AUG 1
JULY 1
JUNE 1
MAY 1
APRIL 1
MARCH 1
FEB 1
JAN 1
20
40
60
80
100
120
140
160
NO. OF RAINY DAYS

GRAPH 11

NATURE OF THE RAINY SEASON

In order to portray more accurately the character of the succession of daily weather types at the beginning of the monsoon period, during the mid-monsoon and at the end of the period, eleven graphs were drawn. For every station, tables were constructed to show the sequence through the entire year of dry and wet days recorded during each of eleven years for which data was available. Both the number of occurences of rainfall and grouping of rainy days was taken into account in constructing a final table. This final table listed the mean sequence of dry and wet days for a "normal" year at the station under study. These final tables are expressed in graph form. See graphs 1 through 11.

On these "normal weather sequence" graphs the X axis represents the number of rainy days and the Y axis the number of dry days. Thus a station with 365 consecutive days having rainfall of one one-hundredth of an inch or more in a normal year would be represented by a horizontal line and a station with 365 dry days per year would be shown as a vertical line. The intersection of the X and Y axis at the lower left corner of the graph represents January 1st and the end of the line at the upper right hand corner of each graph represents December 31st. The point on the graph representing the first day of each month is indicated.

The figures along the X axis represent the cumulative number of expected rainy days since January 1, while figures on the Y axis represent the total number of dry days since the beginning of the year. Thus the yearly total number of wet and dry days at any station may be obtained by reading the coordinates at the right end of the graph and the normal cumulative total of such days to any date during the year may be found by reading the coordinates for that date. At the scale used in graphs 1 through 11 each grid line represents two days.

To obtain a quick idea of the type of weather which might normally be expected for the next two weeks from any date at any station the user has only to locate the appropriate graph and find the period under consideration. Where the graph is horizontal the normal pattern indicates rain; where the graph is vertical the normal pattern is for dry weather. Where the line alternates, so, most likely, will the daily weather sequence.

By the very nature of the variability of weather it is clear that such graphs have little predictive value for periods as short as a day or two. It is equally true that such graphs have greatest accuracy and predictive value where the line approaches either the horizontal or the vertical position. The graphs do, however, portray the normal character of the weather year with clarity and simplicity as may be pointed out dramatically by comparing the graphs for Rangoon and Mandalay.

At Rangoon the year begins with a pronounced dry season. During the months of January and February only one wet day is normally experienced and this usually occurs near the end of February. The graph shows February 24th as the mean date for this single wet day. The normal year's second wet day is most likely to occur in the third week of March and shows on the graph as March 20th. During April four of the thirty days may be expected to be wet; these wet days often occur as two sequences of two wet days each separated by four dry days. From April 22nd until May 6th the graph shows a dry period, but from May 6th on, a period of intermittent wet and dry days extends to the 17th of May. During this period surface winds are variable but they come more and more frequently from the south and southwest. Surface heating is intense and conditions are ripe for convectional activity. Local thunderstorms increase in frequency and in severity and herald the approach of the true monsoon rains. This time of the "little monsoon" is also a period when severe cyclonic depressions form in the Bay of Bengal and occasionally enter the Irrawaddy Delta or cross the Arakan Coast causing considerable wind damage and torrential rains.

From May 18th until October 1st the number of days with rain far exceeds the number of dry days. This truly is the monsoon period. As defined in the preceding section the monsoon rains are said to begin with the first rainy day of a sequence of twenty days, eleven of which are wet. Clearly the rainy season begins on the 6th of May during a "normal" year at Rangoon. As was pointed out above, this date fluctuates from year to year and represents only the average date over a number of years.

It should be emphasized that the transition from dry to rainy season is not accomplished in a single day but rather is marked by a period of alternating wet and dry spells. At Rangoon this transition is accomplished in 12 days while at Myitkyina and Falam the shift takes well over a month of alternating wet and dry periods, with neither being clearly able to dominate the weather. At Mandalay the only period which normally meets the above definition of monsoon rains extends through the last two weeks of August and the first week of September. Pakokku represents the heart of the Dry Belt and a careful study of its graph will indicate that during a "normal" year there is no period which meets the definition of monsoon rains. Clearly however, Pakokku does show a distinction between the dry season and the wetter season. The wetter period begins at about the 15th of May and extends through the first week of October. Throughout this wet season at Pakokku, as at Mandalay, the day-to-day weather is characterized by a sequence of from one to five days of dry weather followed by a series of from one to four days with precipitation.

Throughout all of Burma outside of the Dry Belt a pronounced period of monsoon rains prevails from mid-May approximately until the last week of September at which date the dominance of wet days over dry days begins to lessen. The graph for Rangoon indicates that even in the midst of the rainy season a few clear dry days are to be expected. Thus June exhibits two such days, approximately a week apart, and July shows a single dry day. At the beginning of the third week of August two successive days are apt to be dry and in September there are four such days. From October first through November first

A small farm village 50 miles northwest of Mogaung in the Kachin State. Here rainfall of approximately 120 inches is distributed over almost 150 rainy days each year.

Rangoon normally enjoys an equal number of wet and dry days. This is the period of the retreating monsoon.

The transition from rainy season to dry season varies in date of occurrence as does the onset of the monsoon rains. While the transition at the beginning of the rains is accomplished in less than two weeks the transition at the end of the rains is spread over a full month. At Rangoon November and December are dry months normally exhibiting only five and one wet days respectively.

The graph for Akyab shows a marked similarity to that of Rangoon. At both stations the onset of the rains is quite abrupt while the end of the rains is marked by a much longer transition. Akyab averages almost twice the total rainfall recorded at Rangoon, yet shows slightly fewer rainy days. Clearly the precipitation per wet day is far greater than at Rangoon. The graph for Papun is hardly distinguishable from those of Rangoon and Akyab except that the end of the monsoon is slightly shorter and the transition period at either end of the rainy season is approximately equal in length.

Stations such as Falam, Myitkyina and Putao in the mountainous northern and northwestern portions of the country also show very close similarity one to the other. The range of number of rainy days is only from 148 to 152 despite the fact that total precipitation varies from 66 inches at Falam to 154 inches at Putao. In all three cases January is a dry month while February, March, April and May show an increasing frequency of wet days leading up to the onset of the monsoon in June. The transition from dry to wet is not as sharp and clear here as it is at Rangoon, Akyab and Papun. Falam, Myitkyina and Putao also exhibit rainy seasons interrupted by more frequent dry periods than were found at Rangoon.

Mandalay and Pakokku illustrate conditions in Central Burma's Dry Belt while Prome shows conditions transitional between the wet coastal monsoon areas and the Dry Belt. Mergui demonstrates seasonal weather changes representative of the southern portions of the Tenasserim Coast and Taunggyi is perhaps typical of the march of seasons on the Shan Upland.

DIURNAL VARIATION OF RAINFALL[1]

Long time residents of Burma have learned from experience that to plan any shopping trip or social engagement between noon and seven in the evening during the monsoon is to invite a drenching from the torrential rains. Trips are made early in the morning and dinner engagements are delayed until at least eight o'clock in the evening partly in an attempt to avoid getting soaked. The hours between two and five in the afternoon are avoided at almost any cost for to venture outside at this time of the day is considered sheer folly. From about one to three o'clock many shops, offices and banks are closed and even the bazaars are quiet and lethargic. The transplanting of rice comes to a virtual halt during the mid afternoon hours and even the taungya operators take a long siesta. This rhythm of life in Burma is so well defined and so widespread as to appear clearly to be an adaptation to environmental conditions. As has been demonstrated in an earlier study [2] these are the hours of oppressive dry season temperatures; these are also the hours of heaviest monsoon rainfall. These are hours when physical activity is least pleasant during a major portion of the year. These are hours to be avoided.

Little data has been collected to verify the widely accepted facts concerning diurnal rainfall patterns. Texts are full of statements such as: "rains are of a thundery type usually occurring in the afternoon or early evening" or "the heaviest falls are recorded in the afternoon hours", but seldom are such statements backed by data. S. S. Lal's study of hourly rainfall at Mingaladon gives substance to the widely held beliefs concerning the daily rainfall pattern.

During a period of slightly over nine years, from September 1932 through December 1941 a self-recording raingauge operated first by the India Meteorological Department and later by the Burma Meteorological Department was in use at Mingaladon Airport. The site was 12 miles north of Rangoon, at an elevation of 79 feet above sea level, near the edge of a wooded plateau and midway between two large lakes. The rainguage operated in a standard observatory enclosure at the edge of the airport runway and at a height of 30 inches above the ground.

The total rainfall over the nine year period, October 1, 1932 - September 30, 1941, and the total number of rain-hours for each of the 24 hours of the day for each of the four seasons of the year was tabulated and plotted. See graph 12.

Cool Season. This season, defined by Lal as the months of December through March, represents what is clearly the driest portion of the year. Over the nine year period a total of 13.80 inches of rain fell during these four months and these were recorded during a total of 100 rain-hours. The graph shows that during this season the greatest volume of rain fell during the hours from 2-4 in the afternoon with a second peak at 7 o'clock in the evening.

This season as a whole recorded only one and one-half percent of the total precipitation, but of that small total slightly over 70 percent fell between the hours of 6:00 a.m. and 8:00 p.m. By contrast the hours from midnight to 6:00 a.m., representing one-fourth of the entire day, recorded only slightly over 11 percent of the rainfall and were the driest hours of the season. The wettest month of this season was December which recorded afternoon maximums, while in January, February and March no rainfall was recorded in the nine year period between 10:00 p.m. and 5:00 a.m.

Hot Season. The hot season is defined as the months of April and May and is a period of intensive heating, unsettled air mass movement and intensive convectional activity. These two months recorded a total of 13 percent of the yearly rainfall, much of it from thunderstorms. The greatest rainfall in any one hour period occurred between 1:00 and 2:00 p.m., which hour recorded 10 percent of the season's total. The graph shows a marked peak in precipitation during the warmest part of the day from 10:00 a.m. to 7:00 p.m. The peak is also noticeable in terms of the number of rain-hours concentrated in this part of the day.

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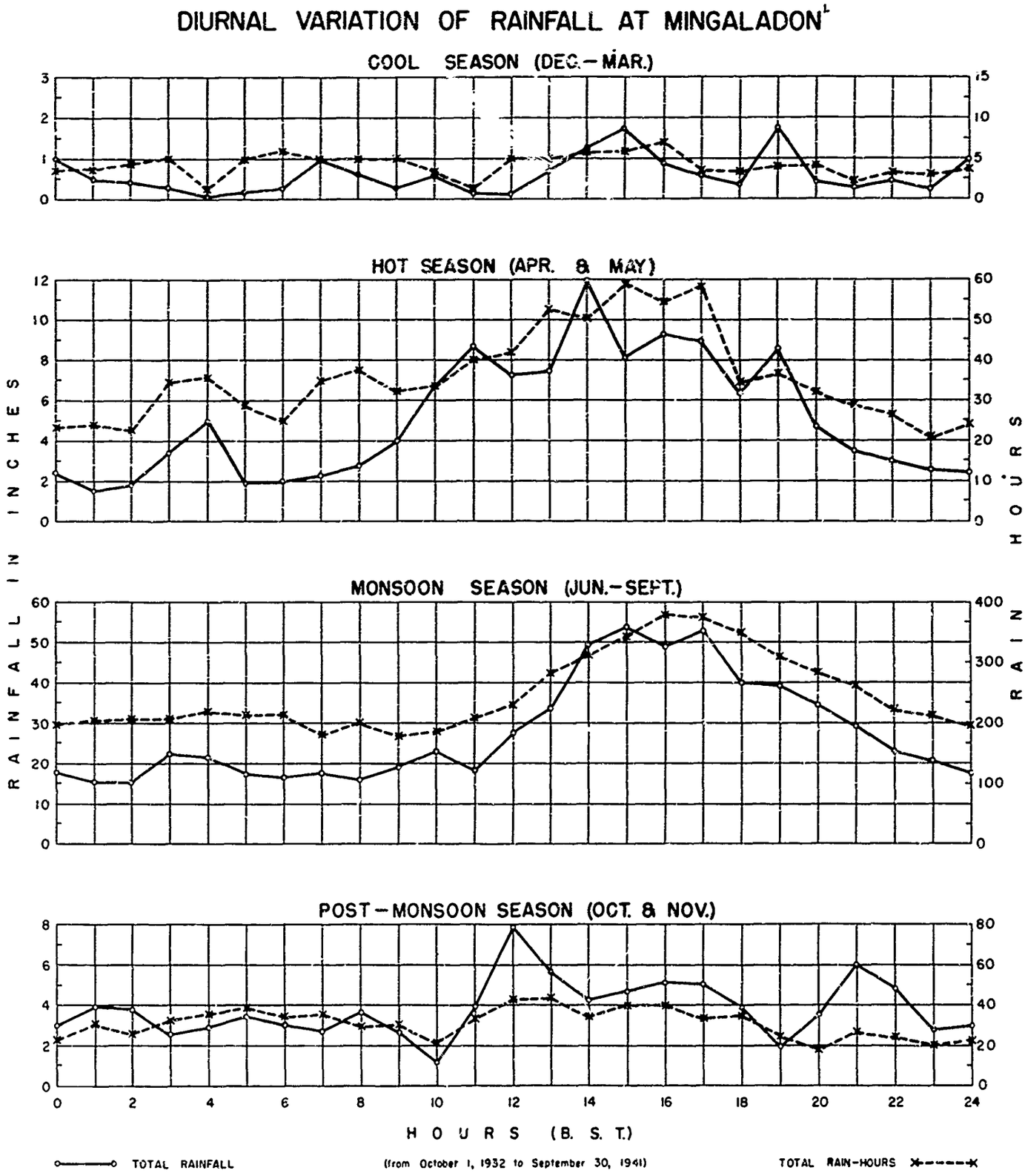
1. Much of the material in the following paragraphs is derived from a single excellent source: Lal, S.S., "A Study of Hourly Rainfall at Mingaladon Airport (Burma)",
2. Huke, R. E., **Temperature Change With Elevation in Burma**, Indiana Univ., Foundation, Bloomington, Indiana, 1962, 143 pp.

RAINFALL IN INCHES


DIURNAL VARIATION OF RAINFALL AT MINGALADON
COOL SEASON (DEC.–MAR.)
HOT SEASON (APR. & MAY)
MONSOON SEASON (JUN.–SEPT.)
POST–MONSOON SEASON (OCT. & NOV.)
RAINFALL IN INCHES
HOURS
RAIN
0 2 4 6 8 10 12 14 16 18 20 22 24
HOURS (B. S. T.)
TOTAL RAINFALL
(from October 1, 1932 to September 30, 1941)
TOTAL RAIN-HOURS

GRAPH 12

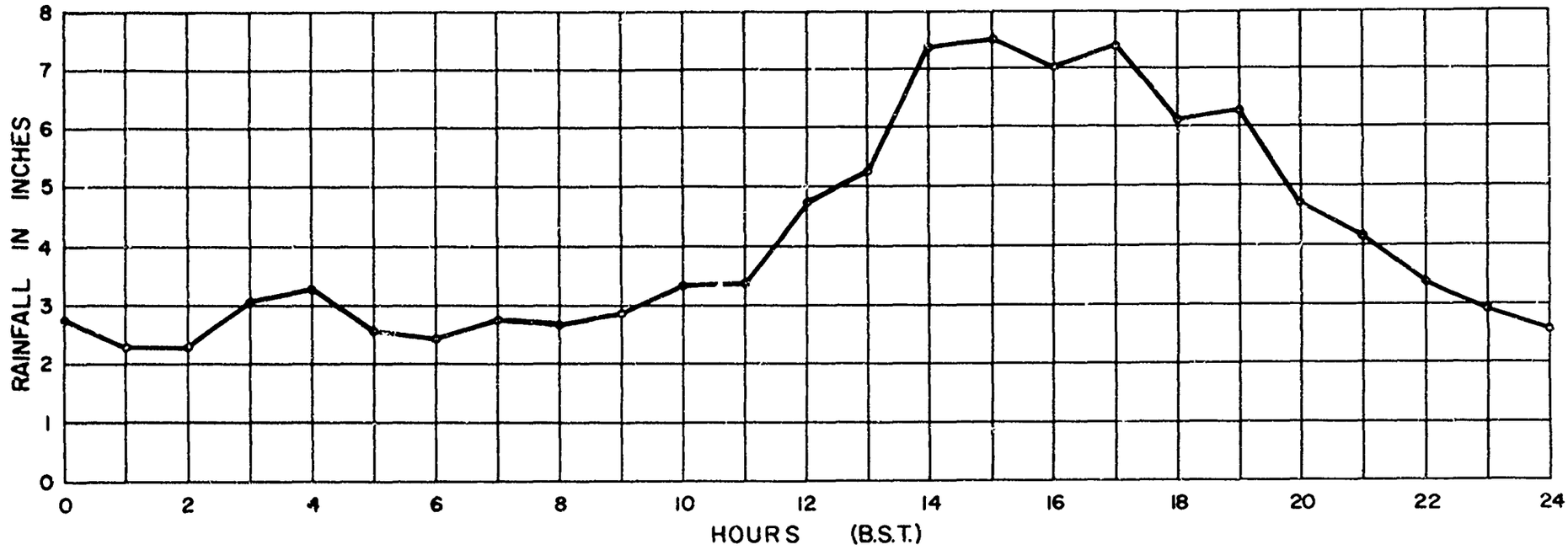
At most stations in Burma the greatest concentration of rainfall during the 24 hour period is between 1:00 and 5:00 p.m. At a station such as Sinlumkaba on the day the above picture was taken, such data seems insignificant. Heavy rainfall throughout the daylight hours deposited over 16 inches of water.

Monsoon Season. Lal defines the monsoon season as the four month period from June through September and his data indicates that 75 percent of the year's rainfall occurs during this period. The graph again shows a very pronounced maximum between noon and 8:00 p.m. These eight hours recorded 53 percent of the total precipitation while an equal period from midnight to 8:00 a.m. measured only 21 percent. The wettest single hour was from 2 to 3 p.m. with the 4 to 5 p.m. period a close second. The driest hours were from midnight to 2 a.m. with totals only slightly more than one-quarter of the wettest period.

Post Monsoon Period. This season includes the months of October and November and shows a marked decrease in rainfall as contrasted with the monsoon season. Eleven percent of the year's rainfall occurs in these months with October having 70 percent of the total. Once more the lion's share of the rainfall takes place during the early afternoon and evening hours. Late evening and morning hours are the driest.

Year. Graph 13 is an attempt to portray the mean daily variation of rainfall at Mingaladon from the data gathered by Lal. If the nine year period of observation can be accepted as producing acceptable mean figures then this graph represents the expected hourly distribution of rainfall for a "normal" year. A longer period of observation would be highly desirable and would probably result in smoothing out the curve although the salient features would be expected to remain much the same as they are shown.

MEAN DIURNAL VARIATION OF RAINFALL DURING THE YEAR AT MINGALADON



GRAPH 13

Clearly rainfall is not evenly distributed throughout the day. Between 1:00 and 5:00 p.m. rainfall reaches a marked peak. The totals for the year taper off gradually during the evening hours and reach a well defined minimum between midnight and 2:00 a.m. During the morning hours, right up until 11:00 a.m., annual rainfall totals remain almost constant hour for hour. From 11:00 a.m. to 1:00 p.m. totals build up rapidly toward the afternoon peak.

The hot season afternoon maximum rainfall appears to be closely related to convectional storms but the monsoon season afternoon maximum cannot be explained as easily. Certainly at that season convection plays a part in peaking the rainfall but with greater cloud cover and considerably lower surface temperatures it seems reasonable to expect convectional rainfall to be of relatively less significance in the monsoon season than in the hot season. How then may the marked afternoon precipitation be explained?

During the monsoon season the flow of air over Mingaladon and other locations in the Irrawaddy and Sittang Valleys is from south to north as was pointed out in a previous section. During these same months there is a marked daytime increase in temperature between locations in the Irrawaddy Delta and the Dry Belt of Central Burma [1]. This temperature difference results in a decreasing pressure gradient from south to north which is strongest during the early afternoon hours and least well developed during the early morning. The diurnal increase and decrease in pressure gradient leads to marked fluctuations in the speed of air flow over areas south of the Dry Belt. Thus at Mingaladon air movement reaches its maximum speed at about 3 or 4 o'clock in the afternoon, some two hours after the maximum pressure gradient is achieved. The increase in speed of movement of the warm moist air flowing from the Bay of Bengal and the Gulf of Martaban apparently favors the development of conditions of instability within the air mass itself and thus encourages precipitation.

1. See Huke, R. E., op. cit., pp. 15-18 and Sir John Eliot, **Memoirs of the India Meteorological Dept.**, Vol. XVIII, Part I, p. 49

ANNUAL VARIATION OF RAINFALL

In previous paragraphs it has been pointed out that the rainfall varies considerably in volume from place to place within Burma and that at any given location precipitation varies from hour to hour throughout the day. Reference to table 6 will indicate that at any given station rainfall totals for the year also vary markedly from one year to the next. The seven stations used to compile tables 6, 7 and 8 were chosen to represent conditions in widely diverse sections of the country, ranging from the Tenasserim and Arakan Coastal Regions to the Irrawaddy Delta, the Shan Upland and the Dry Belt. Within each of the regions, stations were chosen on the basis of the length of record available and on this author's evaluation of the reliability of the data.

It will be noticed that the average rainfall for the 21 years shown on the table varies considerably from the "normal" figures given in the final column. In gross volume the difference is greatest at Akyab where the long term "normal" is recorded as 203.37" but where the 21-year average was only 190.76". At Pakokku, on the other hand, the 21-year average was greater (as opposed to less) than the "normal", the respective figures being 25.84" and 23.91". Interestingly enough, in each case the difference between the 21-year average and the "normal" is approximately 7 percent. Of the seven stations shown in the table, three recorded 21-year averages lower than the "normal" while four were higher than "normal". The total of all seven 21-year averages was 3.43 percent lower than the total of the seven "normal" figures.

Table 7 uses the same stations and the same data as does table 6 but for each station-year the percentage of variation from the 21-year average has been substituted for the actual rainfall figure. The station showing the lowest mean annual variability is Mergui while the variability is greatest at Pakokku. All other things being equal, theory dictates that stations with the greatest total volume of rainfall have the least annual percentage variation and that the driest stations have the greatest variation. Theory and fact coincide well for the seven stations studied except in the case of Mergui and Akyab. Akyab, with a 21-year average rainfall measuring forty inches greater than that at Mergui, shows a significantly higher variability.

Mergui is located in the far south of Burma in an area falling under the influence of the inter-tropical front during a major portion of the rainy season. Akyab, by contrast, is at the northwestern end of the Arakan Coast where the inter-tropical front plays a relatively minor part in producing rainfall but where the effect of the summer monsoon is strongest. Perhaps the difference in variability indicates that the monsoon winds are less reliable producers of rainfall than is the inter-tropical front. This question deserves further work in subsequent studies.

Variability from the 21-year average was not markedly consistent year by year throughout the country. For example, during this period the two wettest stations, Mergui and Akyab, both showed variation in the same direction (either positive or negative) only 10 times, just as the law of chance would indicate. In only one year, 1939, did all seven stations show variation in the same direction from the long term average. In six additional years six of the seven stations varied from the average in the same direction but the seventh station shifted in the opposite direction. Furthermore the station out of phase with the rest of the country was not always the same nor, indeed, even in the same region. The misfit shifted from Prome to Pakokku to Mergui to Mandalay.

The mean variability from the 21-year average for the 147 station-years presented is 12.71. For individual station-years the variability ranged from 0.0 to +66.2 and —36.0.

The question of consistency from station to station and between the wet areas and the Dry Belt in the variability of rainfall from year to year was investigated by means of reference to the interannual variability. The interannual variability portrays the sign and the magnitude of the difference of precipitation in successive years. It was thought that this element might be more sensitive to broad patterns of yearly rainfall variations than were the data for variability from the long term average. The same seven stations and the same 21-year period were used to compile the results presented in table 8.

Several interesting and meaningful observations can be made from this table.

Table 6.

Rainfall by Years — 7 Key Stations

Station	1928	1929	1930	1931	1932	1933	1934	1936	1939	1940	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	21-Year Avg.	Normal
Mergui	178.03	183.99	160.68	145.18	149.47	167.47	144.98	145.09	162.36	146.57	163.52	149.37	165.19	140.22	156.77	141.64	146.14	133.08	128.22	137.57	170.22	153.24	161.24
Akyab	203.43	212.98	198.81	202.80	185.07	168.47	168.82	204.82	205.16	198.30	177.25	208.29	217.53	191.67	174.14	189.93	213.07	128.05	162.92	218.83	175.56	190 76	203 37
Rangoon	114.34	98.31	110.94	122.32	87.44	103.90	101.27	116.09	115.23	108.29	125.99	76.38	109.42	104.67	85.37	112.97	91.58	85.37	82.47	121.45	95.00	103.27	99 03
Prome	39.16	44.45	46.18	34.84	38.07	54.42	39.12	62.36	61.93	67.06	46.89	47.30	65.90	48.67	56.98	55.38	51.51	41.60	52.94	54.96	50.09	50.47	46 89
Taunggyi	60.93	65.70	55.92	47.76	74.74	73.47	58.95	64.99	62.50	69.50	66.26	54.94	62.55	59.00	51.67	65.60	55.59	51.24	56.55	67.04	48.25	60.63	68.64
Pakokku	26.69	21.32	34.60	22.17	23.44	32.89	28.14	28.57	26.25	36.91	22.67	31.12	29.43	21.98	21.07	23.91	42.95	16.52	26.55	25.52	27.25	25 84	23 91
Mandalay	45.18	43.40	37.61	23.85	39.02	29.08	30.45	38.34	44.45	37.87	27.98	28.38	26.67	27.98	27.29	31.80	35.16	38.14	27.84	34.00	27.86	33.45	32.47
Total — 7 Stations	667.76	670.25	644.74	598.92	597.25	[illegible]	571.23	660.26	671.73	677.96	630.56	595.78	676.69	594.19	573.29	621.23	636.00	494.01	537.49	659.37	594.23	614.45	635 55

Table 7.

Rainfall — Percent Variability from 21-Year Average

Station	1928	1929	1930	1931	1932	1933	1934	1936	1939	1940	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	Avg. of 21 Years
Mergui	+16.3	+20.0	+ 5.3	— 5.3	— 2.7	+ 9.8	— 5.2	— 5.2	+ 5.9	— 2.6	+ 6.5	— 2.6	+ 7.8	— 8.5	+ 2.6	— 7.2	— 4.6	—13.1	—16.4	— 9 9	—11 1	8 09
Akyab	+ 6.2	+11.5	+ 4.2	+ 6.3	— 3.1	—12.0	—11.5	+ 7.3	+ 7.9	+ 3.7	— 7.3	+ 8.9	+14.1	+ 0.0	— 8.9	— 0.2	+11.5	—33.0	—14.2	+14.1	— 8.4	9 22
Rangoon	+10.7	— 4.9	+ 7.8	+18.4	—15.6	0	— 1.9	+12.6	+11.6	+ 4.8	+22.3	—26.2	+ 5.8	+ 1.9	—17.5	+ 9.8	—10.7	—17.2	—19.9	+17.4	— 7.8	11 65
Prome	—22.4	—11.9	— 8.6	—31.1	—24.8	+ 7.7	—22.6	+23.3	+22.5	+32.6	— 7.1	— 6.4	+30.5	— 3.6	+12.8	+ 9.7	— 1.9	—17.7	+ 4.7	+ 8.9	— 0 8	14.84
Taunggyi	+ 0.4	+ 8.4	— 7.7	—21.1	+23.3	+21.2	— 2.9	+ 7.2	+ 3.1	+14.6	+ 9.4	— 9.5	+33.0	— 2.7	—14.7	+ 8.3	— 8.8	—15.5	— 8.3	+10.5	—20.5	10 54
Pakokku	+ 3.4	—17.5	+34.1	-13.9	— 9.3	+ 27.5	+ 8.9	+10.8	+ 1.9	+43.0	—12.1	+20.5	+13.9	—15.1	—18.6	— 8.6	+66.2	—36.0	+ 4.7	— 1.2	+ 5 8	17.76
Mandalay	+34.9	+29.5	+12.2	—28.7	+16.4	—13.1	— 9.0	+14.3	+32.8	+13.1	—16.4	—15.2	—20.3	—16.4	—18.5	— 5.1	+ 5.0	+13.7	—17.0	+ 1.4	—16.7	16 65
Mean — 7 Stations	14.71	14.81	11.41	17.83	13.60	13.04	8.86	11.53	12.16	16.34	11.59	12.76	13.67	6.89	13.37	6.99	15.53	20.89	12.17	9.06	10 16	12 71

Table 8

Inter-annual Variability of Precipitation
7 Key Stations*

Sequence of Years	All 7 Stations	Only Mdy. Pakokku	Stations Showing		Mdy. - Pakokku	
	% of Variability	% of Variation	Increased Precip.	Decreased Precip.	Increased Precip.	Decreased Precip.
1928-1929	+00.4	— 9.9	4	3	—	2
1929-1930	— 3.8	+11.6	3	4	1	1
1930-1931	— 7.1	—36.3	2	5	—	2
1931-1932	—00.3	+35.7	5	2	2	—
1932-1933	+ 5.5	—00.2	4	3	1	1
1933-1934	— 9.2	— 5.5	3	4	1	1
N.A.						
1938-1939	+ 2.7	+ 5.8	3	4	1	1
1939-1940	— 1.7	+ 5.7	3	4	1	1
N.A.						
1950-1951	— 5.5	+17.5	4	3	2	—
1951-1952	+13.6	— 5.7	5	2	—	2
1952-1953	—12.2	—11.0	1	6	1	1
1953-1954	— 3.5	— 3.2	2	5	—	2
1954-1955	+ 8.4	+15.2	5	2	2	—
1955-1956	+ 2.4	+40.2	4	3	2	—
1956-1957	—22.3	—30.0	1	6	1	1
1957-1958	+ 8.8	—00.5	4	3	1	1
1958-1959	+22.7	+ 9.4	6	1	1	1
1959-1960	— 9.9	— 7.4	2	5	1	1

*These are the same 7 stations for which data was presented in the previous table.

In only 10 of the 18 sequences of years is the sign of the variability in the Dry Belt the same as that for all of Burma. Interestingly, in the two sequences when variability was greatest, 1956-1957 and 1958-1959, the sign was the same in the Dry Belt as in all of Burma. The possible significance of this relationship is severely questioned, however, by the fact that in 1951-1952, the sequence of third greatest variability, the data for all seven stations shows a positive swing of 13.6 percent while the Dry Belt stations show a negative dip of 5.7 percent.

In column two it will be noticed that sequences showing large surpluses or large deficits are often followed by sequences showing the opposite sign. It can perhaps be stated that there is a tendency for major departures from normal precipitation to be compensated for in the subsequent years. No great emphasis should be placed on this observation, however, for it has already been taken into account in determining the long term average.

The two final columns of table 8 deal only with the Dry Belt stations Mandalay and Pakokku and show the number of stations recording increased precipitation and the number recording decreased precipitation for the two-year sequence. In only 8 of the 18 years do the two stations show changes with the same sign. This is approximately the same proportion that would have identical signs by chance according to probability theory. In the 1956-1957 sequence the seven stations showed a total decrease of 22 percent and the variation of the Dry Belt stations was minus 30 percent; of all seven stations, six showed declines, but Mandalay, a Dry Belt station, bucked the trend and recorded a modest increase. There appears to be little direct relationship between annual rainfall variations of the wet coastal areas and those of the Dry Belt. This is undoubtedly due to the fact that precipitation in these two areas is the result of diverse causative factors as outlined previously.

Interannual variability of rainfall in Burma is markedly lower than that found by Landsberg [1] in Ohau. This fact may indicate that rainfall derived chiefly from trade wind sources is less reliable than that from the Southeast Asian monsoon. Further studies on this topic are needed.

1. Landsberg, H. "Statistical Investigations into the Climatology of Rainfall on Ohau (T.H.)", Meteorological Monographs, Vol 1, no. 3, June 1951. pp 7-23.

THE DRY BELT

In the discussion of almost any aspect of the country the area of Central Burma, known in the literature as the Dry Belt, assumes a special significance. This area has served as the hearth of Burmese culture and it was in this area that Burmese civilization achieved its greatest heights. The Dry Belt is distinctive for its low rainfall combined with high temperatures and for the fact that its agriculture, its natural vegetation, its soil types and even its pattern of settlement contrast sharply with conditions found in other parts of Burma. The core area of the Dry Belt is easily identified and almost all authors agree that it centers on the towns of Pakokku and Myingyan and that it also includes the ancient capital at Pagan. The outer limit of the Dry Belt is more difficult to locate, in part because being a climate boundary, it varies from year to year.

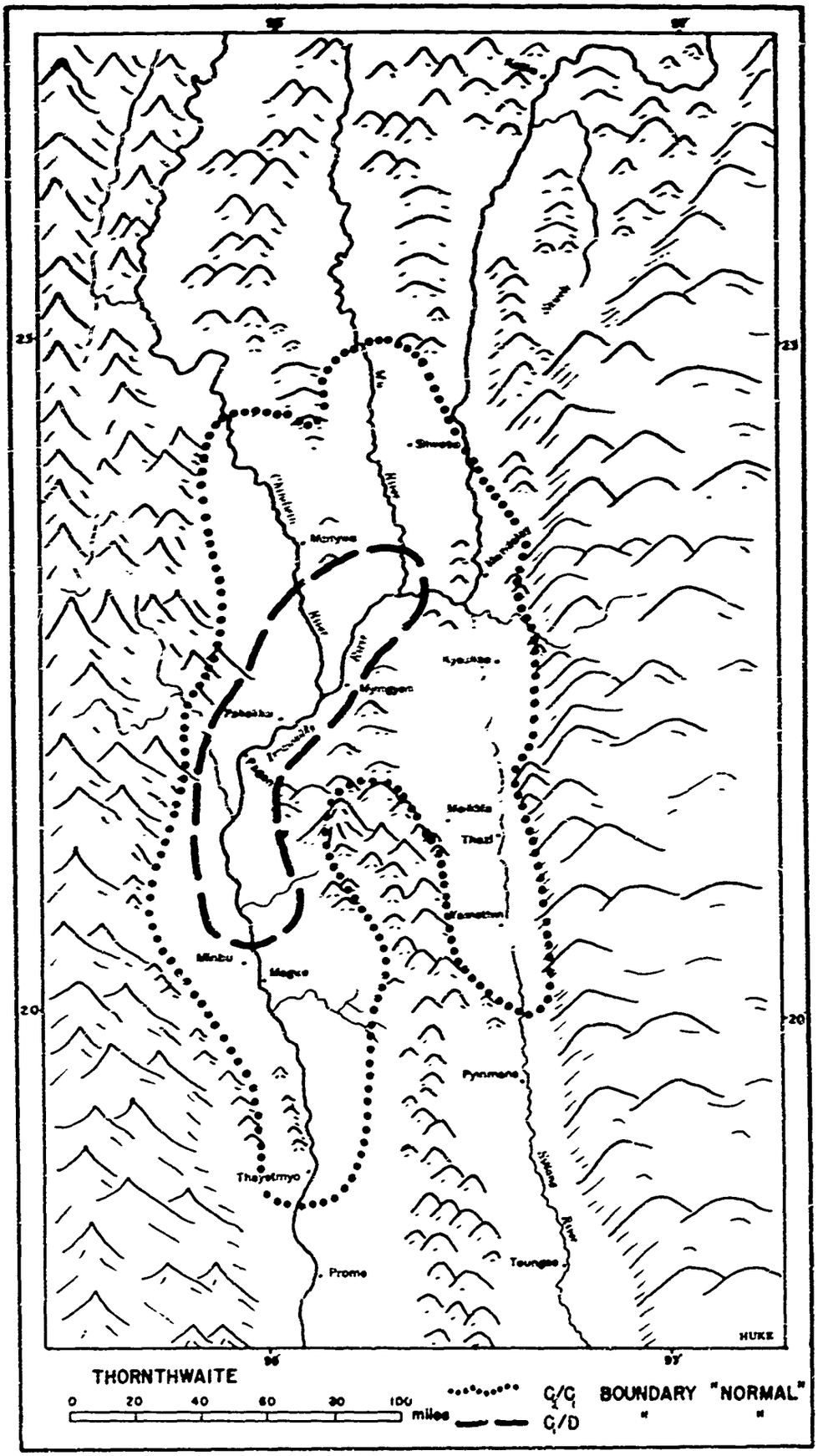
In a study of rainfall in Burma one set of questions which might well be asked deals with this Dry Belt. Where is the Dry Belt? How much variation is there in its size and shape from year to year? Is there a true "core area"? If so where is it?

In an attempt to answer these questions a series of maps has been made using the Köppen and the Thornthwaite systems of classification. Data for all available stations from the latitude of Toungoo and Prome in the south to Katha and Mawlaik in the north and lying between the Shan Upland in the east and the foot of the Arakan Yoma to the west were used. The area involved measures some 360 miles from north to south and has an average width of roughly 120 miles. Within this area are located 63 raingauges with records adequate for use.

1. Data from these gauges is reported in: Burma Meteorological Dept., **Statement Showing the Monthly and Annual Rainfall at Rain-Recording Stations in Burma for the Year**, Super. Gov. Printing and Stationery, Rangoon. Annual.

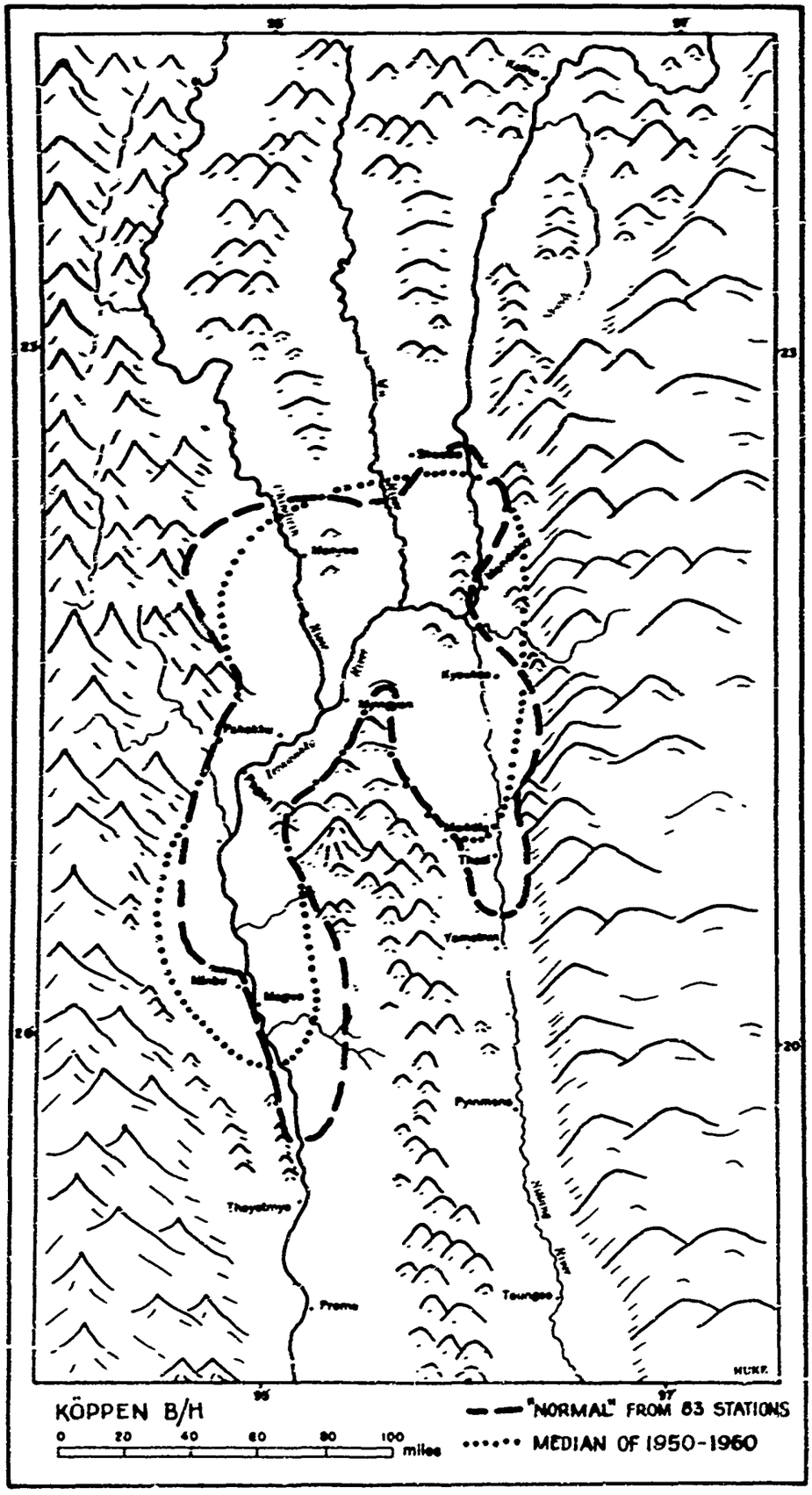
The eastern edge of the Dry Belt is marked by a steep fault scarp which often rises as much as 2,000 feet in a single step. This view is taken from the top of Mandalay Hill.

CENTRAL BURMA



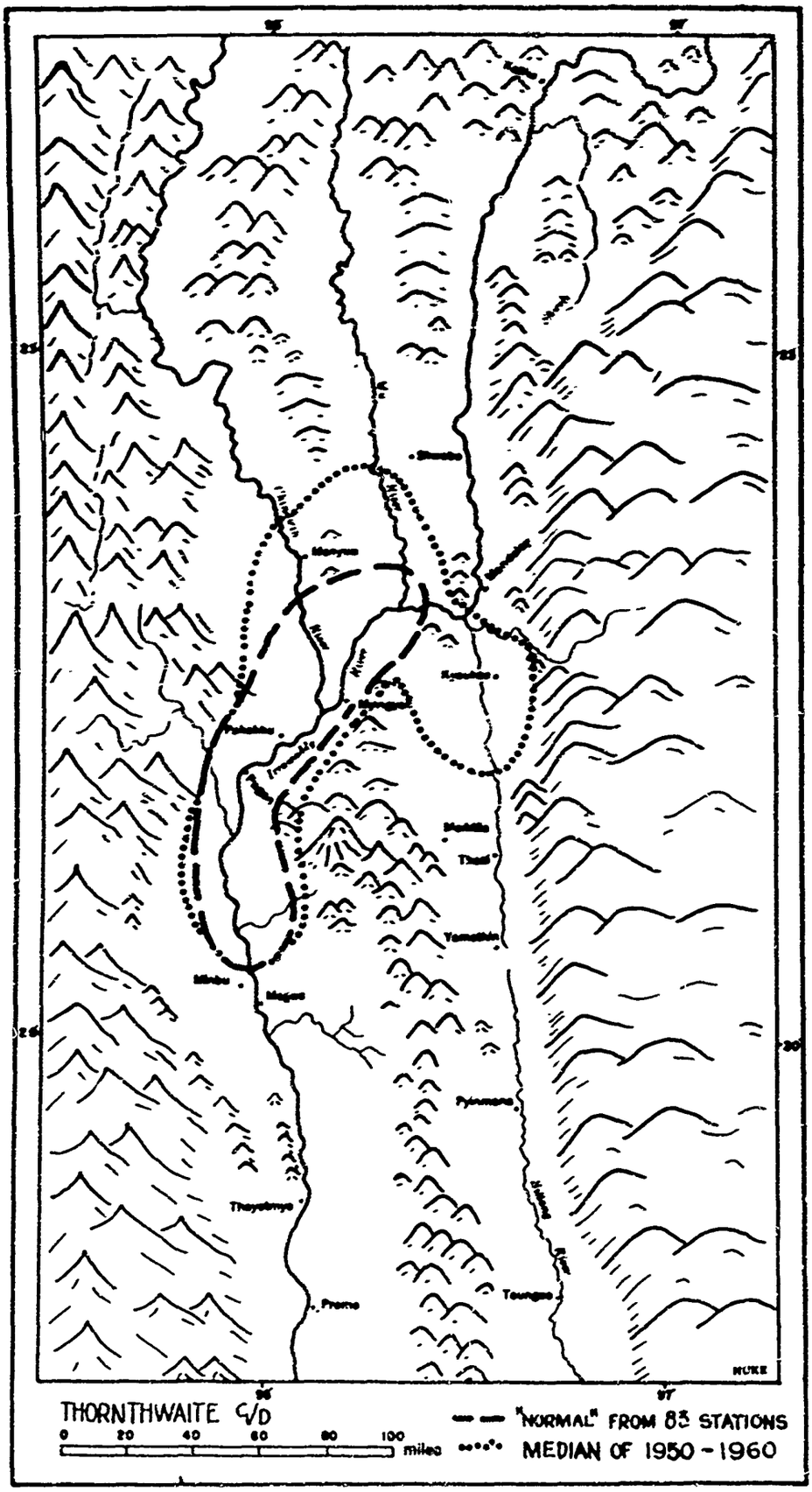
MAP 31

CENTRAL BURMA



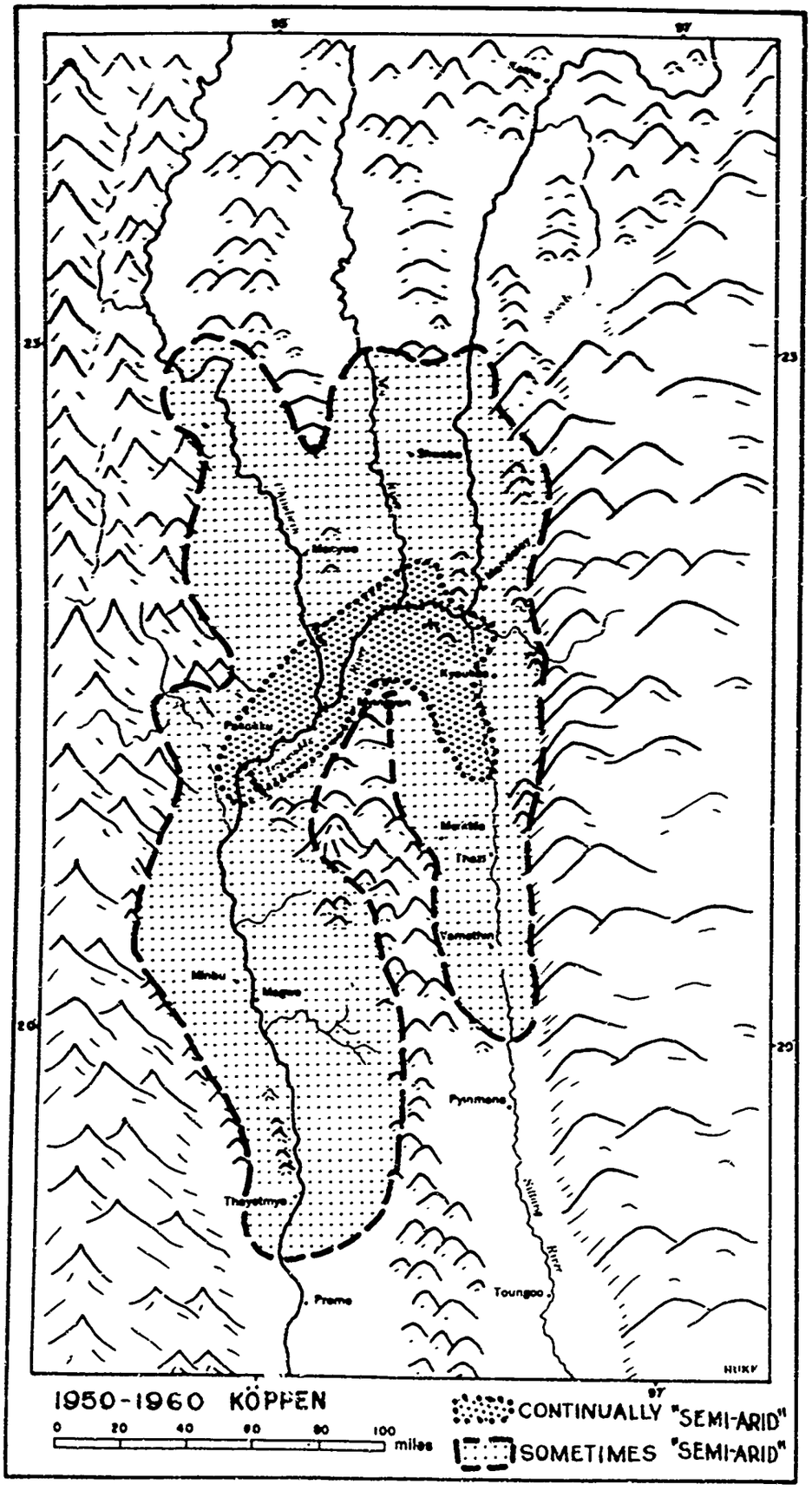
MAP 32

CENTRAL BURMA



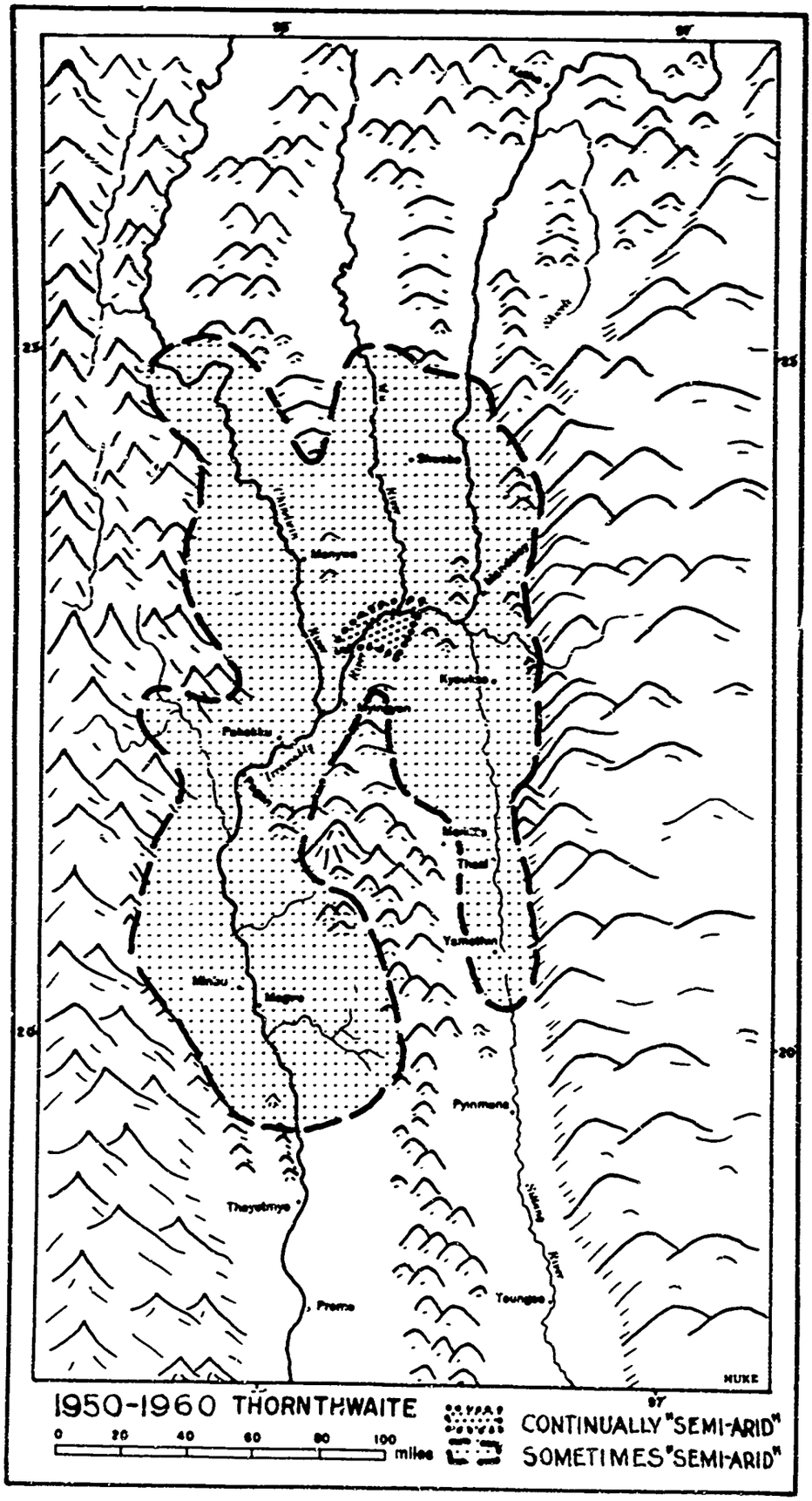
MAP 33

CENTRAL BURMA



MAP 34

CENTRAL BURMA



MAP 35

all stations were able to report data for each month during the eleven year study period, 1950-1960, because of insurgent activity and the lack of sufficient numbers of trained observers. The data available however was sufficient to allow the maps to be prepared with some confidence.

For the Köppen classification there was no question about which line to use as the limit of the Dry Belt since by definition the B climates are termed dry and are the climates in which the potential evaporation during an average year exceeds the precipitation. On all Köppen maps of the Dry Belt the line shown is the boundary between the B climates, inside of the line, and the humid climates, outside of the line. In almost all cases the Dry Belt "B" climates are bordered on both the north and the south by "A" climates. However, in years when the B climates extended further to the north than normal, they were bordered, in Katha and Upper Chindwin Districts, by C climates.

With the Thornthwaite classification the choice of which line to use was more difficult. In Thornthwaite's 1948 classification nine climate types based on the moisture index are presented [1]. The two lines of concern are the dividing lines between C_2, moist subhumid (moisture index of 0 to 20) and C_1, dry subhumid (moisture index -20 to 0); or between C_1 and D, semiarid (moisture index -40 to -20). Map 31 was prepared plotting both lines using the data from all 83 stations. By checking this map against the descriptions in the literature and by asking the opinion of various Burmese scholars it was decided to use the C_1/D boundary in subsequent mapping as this more closely approximated the traditional Dry Belt than did the area enclosed by the C_2/C_1 boundary.

The C_2/C_1 Thornthwaite boundary by definition separates those areas with a positive moisture index and thus a water surplus from those areas with a negative moisture index and a water deficit. In theory this should be the same as the Köppen B/H boundary if the systems were equally precise in their measurements. In fact, using the identical data from Burma's Dry Belt, the Thornthwaite C_2/C_1 boundary lies well outside of the Köppen B/H boundary, as may be seen by comparing maps 31 and 32. In the south the Köppen boundary lies to the north of Thayetmyo, in the Irrawaddy Valley, and Yamethin, in the Sittang Valley, while the Thornthwaite boundary lies south of these towns. To the north, the Köppen boundary lies south of Shwebo and extends up the Chindwin Valley to a point less than 20 miles north of Monywa. The Thornthwaite boundary is located 20 miles to the north of Shwebo and extends up the Chindwin to a point 45 miles beyond Monywa. The total area included within the Thornthwaite C_2/C_1 boundary is approximately 60 percent larger than the area enclosed by the Köppen B/H boundary and includes considerable area recognized by Burmese specialists as lying outside of the Dry Belt.

The Dry Belt is usually described as an area where rice is not raised without irrigation and where agriculture is characterized by a great diversity of crops including an important emphasis on pulses, sesamum and groundnuts. In light of this distinction the following table is of considerable interest.

1. Thornthwaite, C. W., "An Approach Toward a Rational Classification of Climate", **Geographical Review**, Jan. 1948, pp. 55-94.

Table 9

Dry Belt Crop Areas*

	Thayetmyo Dist.	Minbu Dist.
Irrigated area	5,500 acres	132,000 acres
(Major crops)		
Rice	78,000	125,000
Pulses	16,000	45,000
Sesamum	66,000	61,000
Groundnuts	13,000	10,000

*Data compiled from: **Season and Crop Report for the Union of Burma for the Year Ending 30th June, 1958**, Superintendent Government Printing and Stationery, Rangoon 1960. (in Burmese)

Clearly a major portion of the rice in Thayetmyo District is not irrigated while that of Minbu is. Thus Thayetmyo is outside of the Dry Belt despite the importance of sesamum, pulses and groundnuts in the province. These latter crops indicate conditions approaching those of the Dry Belt and indicate a location close to the border. Thayetmyo District would be included in the Dry Belt using the Thornthwaite C_2/C_1 border and excluded from the Dry Belt using the Thornthwaite C_1/D divide.

Map 31 also shows the Thornthwaite C_1/D boundary. This includes an area smaller than the recognized Dry Belt. The contraction is particularly noticeable in Kyaukse, Shwebo and Minbu Districts where irrigated rice is very important. Neither of the Thornthwaite lines appears adequate to define the Dry Belt precisely.

For purposes of observing differences in size and location of the water deficit area from year to year it was decided to use the C_1/D boundary rather than the C_2/C_1 divide. The choice of the C_1/D boundary was also made in an attempt to delinate the core area of the Dry Belt.

The next step was to prepare maps showing the Thornthwaite and the Köppen divides as based on "normal" rainfall and temperature data and at the median position for the eleven year study period. "Normal" data is that supplied by Burma's Dept. of Meteorology and is based on records varying from a minimum of 10 years to a maximum of 74 years for individual stations. The average length of record is 43 years.

The median location of the climate divides was arrived at by plotting the divide for each of the eleven years under study, superimposing the eleven maps and drawing a new line based on the median position of the eleven yearly lines. Map 32 shows the normal and median lines according to Köppen and map 33 does the same for the Thornthwaite system.

The normal and 1950-1960 median lines according to the Köppen system include approximately the same total area and show only minor variations in location as may be seen on map 32. The Thornthwaite system on the other hand shows major differences between the normal and the median, with the median location including 65 percent greater area than the normal. The extension is particularly noticeable near Kyaukse. This was apparently caused by the fact that while yearly total rainfall was below normal during the 1950-1960 period this deficiency was most marked in the month of October which, according to "normal" data, is the wettest month of the year. Table 9 shows that of the ten years for which data is available Ngapyaung Wier, six miles east of the town of Kyaukse, showed above average rainfall only twice and significantly below average rainfall seven times during October.

The next step was to use the two systems of classification to identify the core area and the absolute outer limits of the Dry Belt. The core area was taken to be that area which during the eleven study years fell continually within the dry region and never enjoyed a single wet year. The absolute outer limit of the Dry Belt includes all areas which were inside the boundary at least once during the study period.

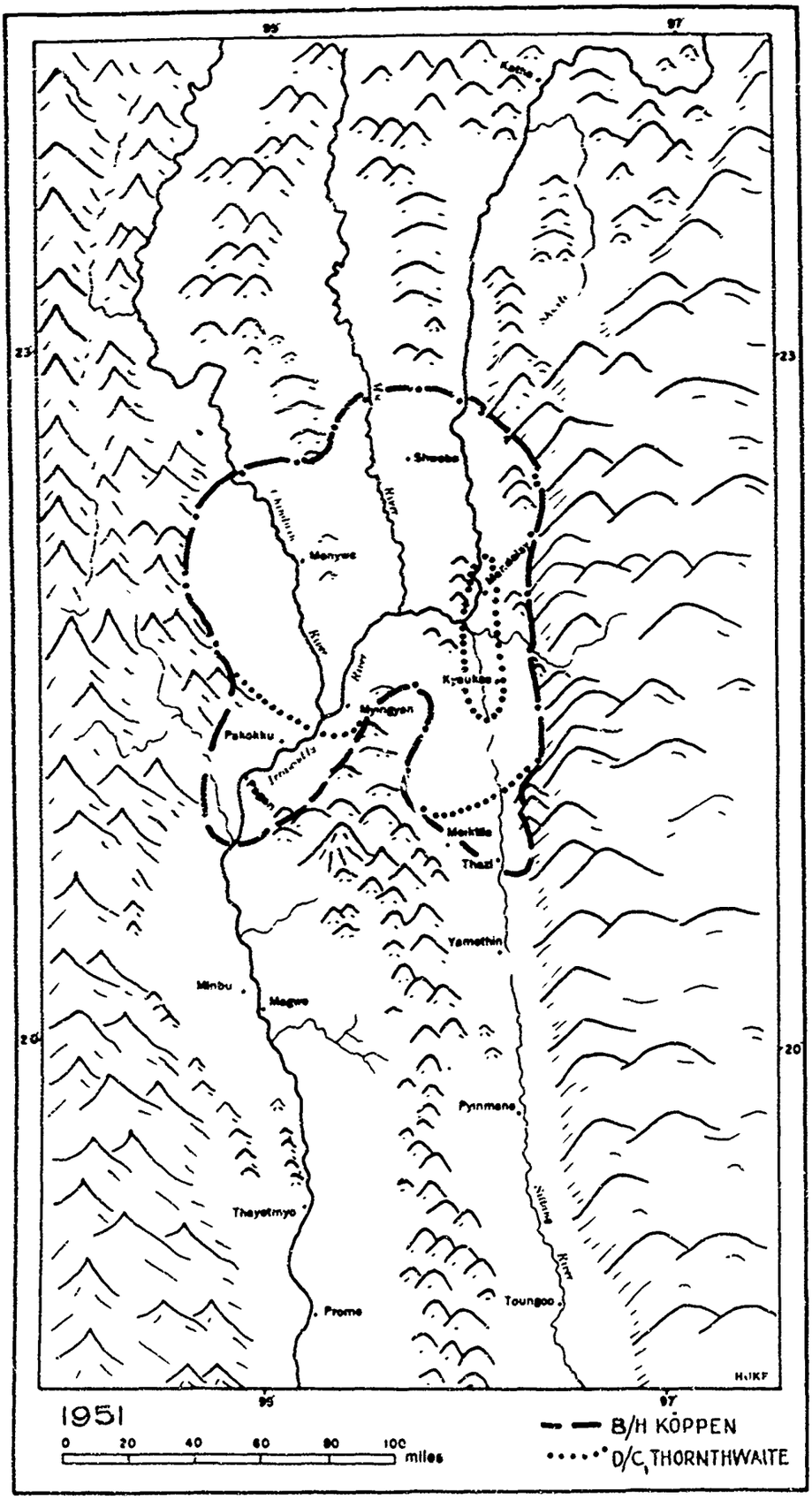
Again interesting contrasts were observed. The maximum extent of the dry zone was strikingly similar. Köppen's boundary extended somewhat further south in both the Irrawaddy and the Sittang Valleys. In the Irrawaddy the maximum limit approached within 15 miles of Prome, some 40 miles south of the Thornthwaite limit, while in the Sittang Valley the maximum limit fell 20 miles north of Pyinmana, 10 miles south of the Thornthwaite boundary. In other areas the maximum extent of the two was so close that measurements of the differences were not considered as significant

In terms of gross area covered the outer limit of the Köppen B/H boundary enclosed 19,250 square miles while Thornthwaite's C_1/D boundary covered 17,250 square miles or 2,000 less than the former system.

The core areas of the 2 systems showed marked contrasts, with the Köppen core area being of considerable extent and covering what, according to the literature, is the traditional center of the Dry Belt. Köppen's core area covers 2,430 square miles or 13 percent of the maximum dry area for the 11 year period.

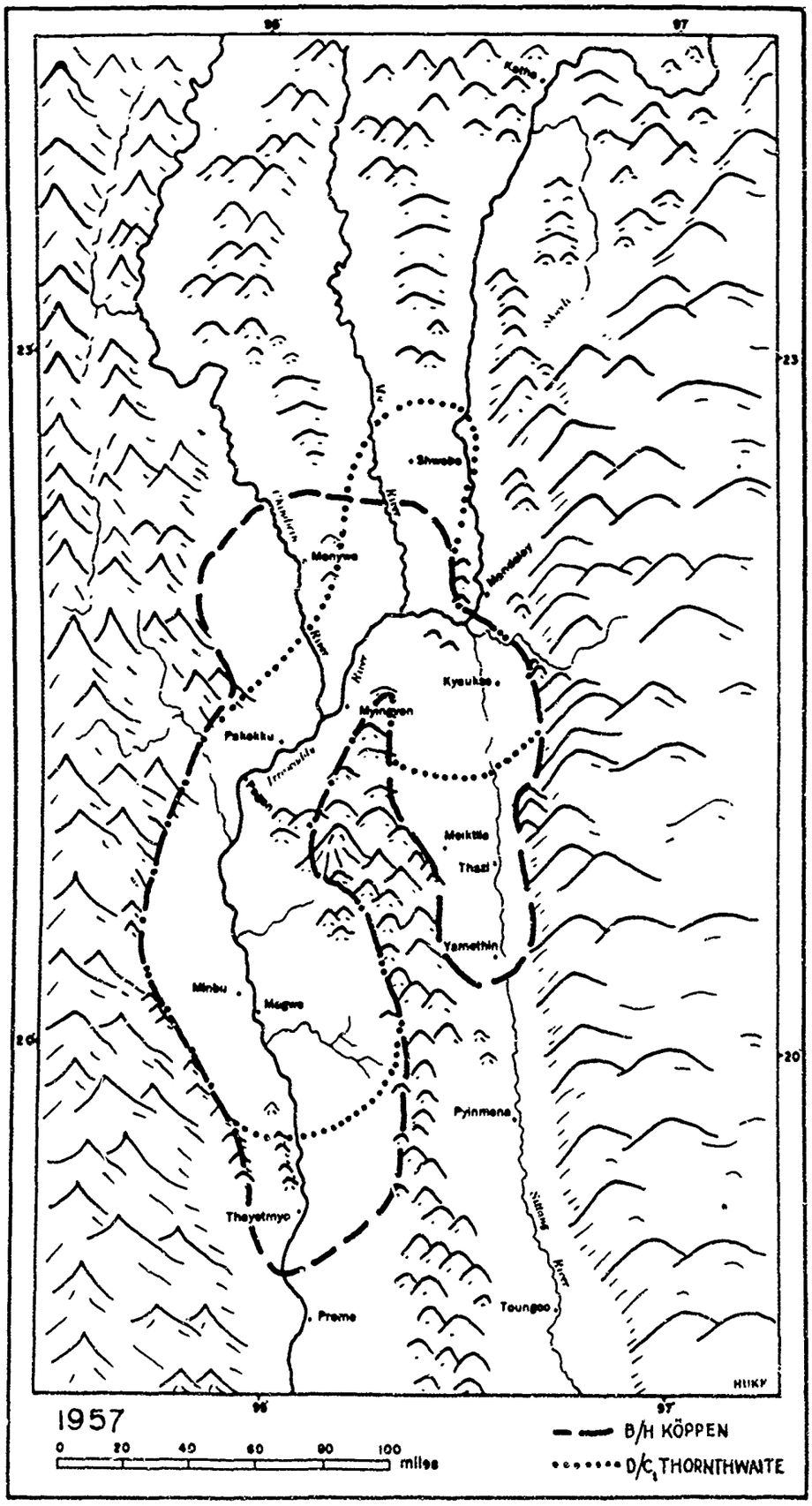
Thornthwaite's core area is far smaller than Köppen's and excludes such traditional Dry Belt centers as Pagan, Pakokku and Myingyan. This core area covers only 257 square miles or only 1.5 percent of the maximum extent of dry areas.

CENTRAL BURMA



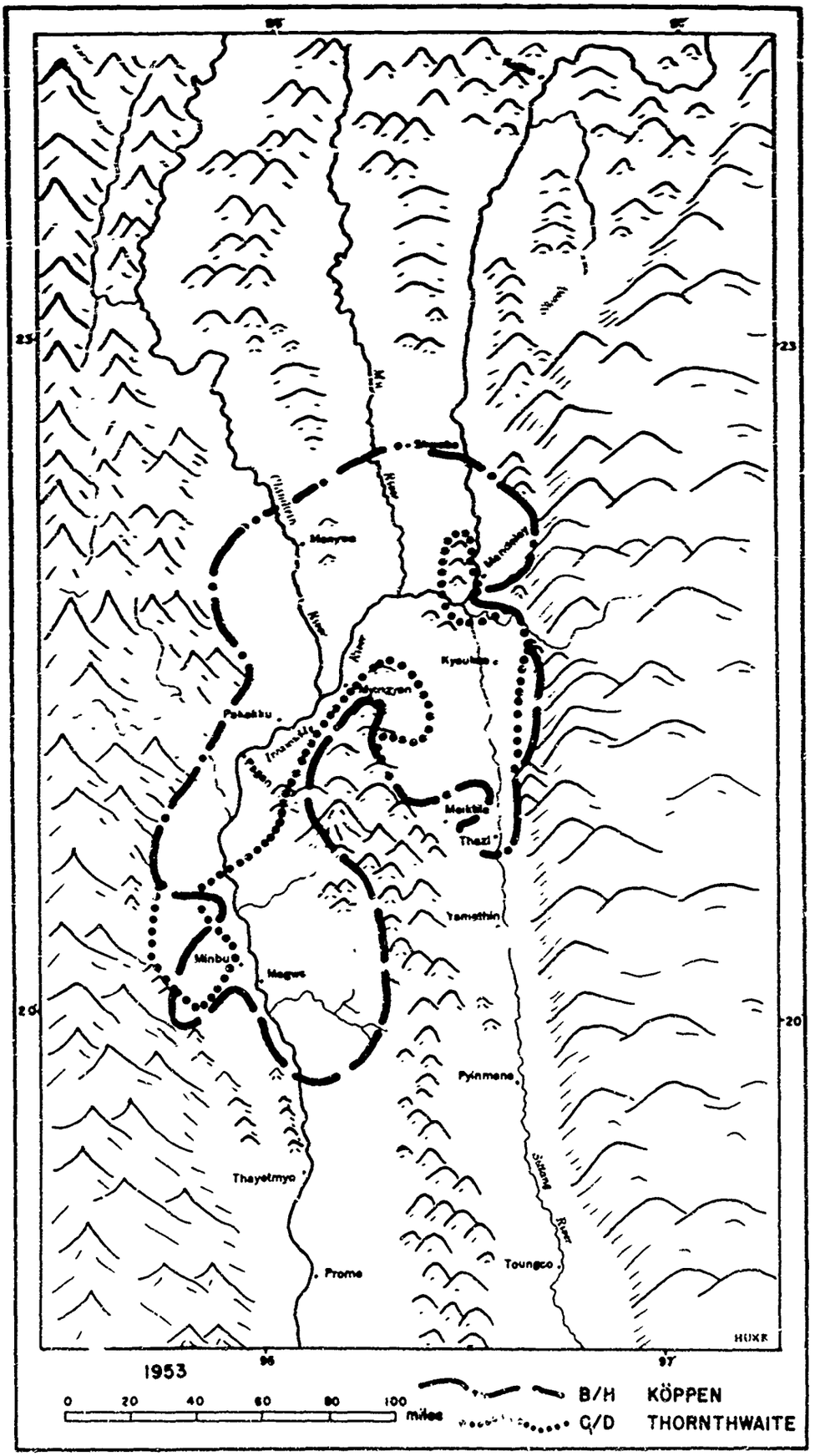
MAP 36

CENTRAL BURMA



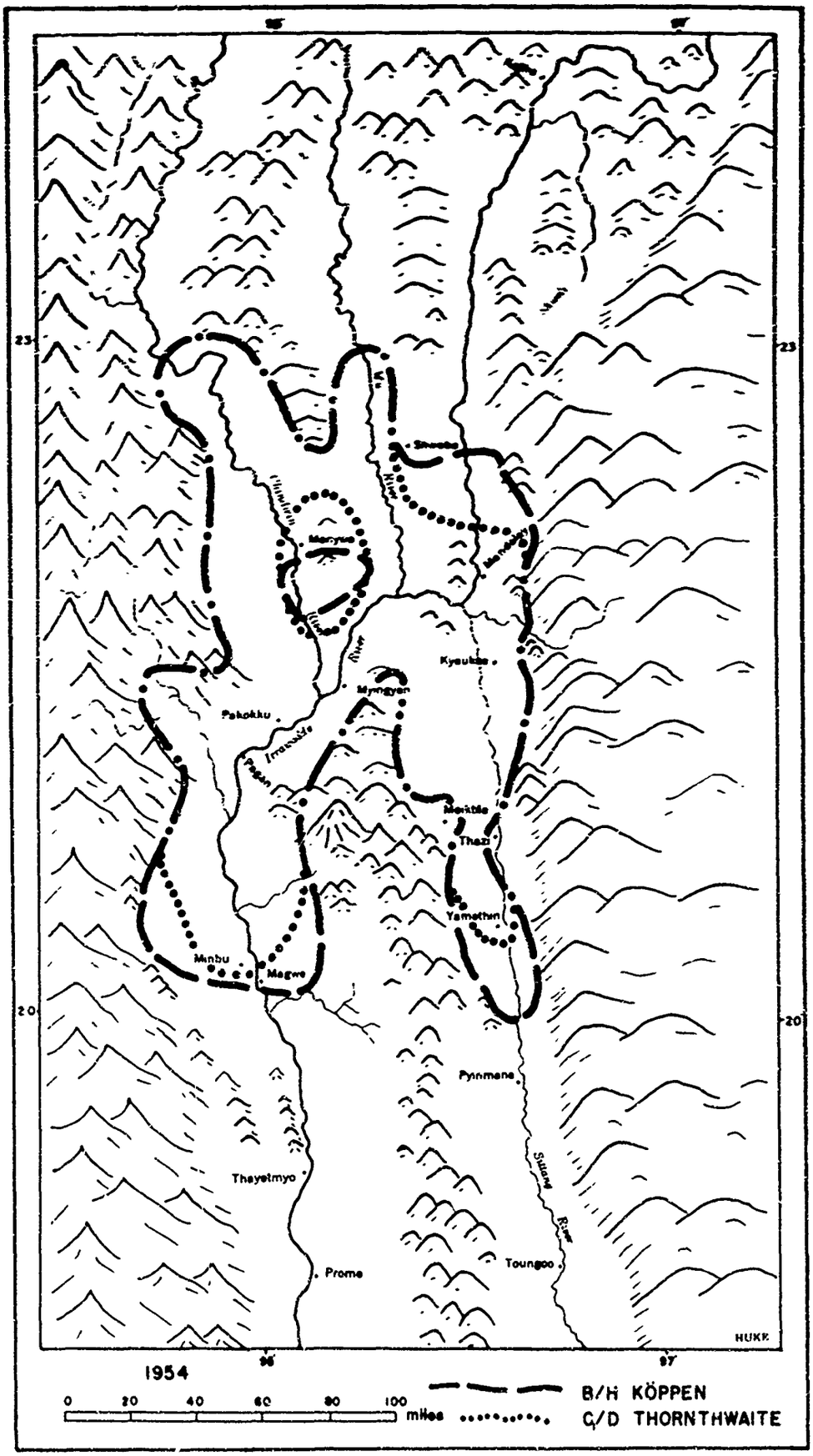
MAP 37

CENTRAL BURMA



MAP 38

CENTRAL BURMA



MAP 39

Table 10.

Ngapyaung Wier (E. of Kyaukse)
Rainfall in inches

	Sept.	Oct	Nov.	3 Months Total	Yearly Total
"Normal"	5.03	6.54	1.89	13.46	32.61
1950	10.03	11.09	3.81	24.93	40.84
1951	4.02	9.57	0.00	13.59	24.8[illegible]
1952	2.43	6.78	2.35	11.56	20.37
1953	1.66	4.91	1.48	8.05	29.51
1954	4.79	4.96	0.00	9.75	
1955	5.81	1.50	4.60	11.91	29.57
1956	6.63	5.03	0.61	12.27	26.23
1957	5.11	1.99	0.00	7.10	19.47
1958	n.a.	n.a.	n.a.	n.a.	n.a.
1959	4.77	3.31	0.00	8.08	29.21
1960	5.60	5.89	0.00	11.49	21.17
Total	50.90	55.00	12.85	118.78	241.24
Average for 10 Years	5.09	5.50	1.29	11.88	26.80
Change from Normal	+.06	—1.04	—.60	—1.58	—5.81
Percent Change from Normal	+1	—16	—31	—12	—18

Köppen's core area is adz like in shape as may be seen on map 34. It extends south of Mandalay some 50 miles and covers both sides of the Irrawaddy Valley from Sagaing, just south of Mandalay, past the junctions of both the Mu and the Chindwin Rivers to a point a few miles south of Pagan. The Thornthwaite core area, by contrast, is limited to a small triangular area at the junction of the Mu with the Irrawaddy, as is illustrated by map 35.

A series of eleven climate year maps was constructed showing the area included in the Dry Belt by each system for each of the years. Four of these maps representative of different conditions are reproduced as maps 36, 37, 38, and 39. These four maps illustrate rather well the variations both in size and in location of the Dry Belt from year to year. Perhaps more than anything else they demonstrate that the "normal" and median boundaries shown on maps 32 and 33 have little relationship to actual conditions in any given year. These four maps in turn emphasize the importance of the maps of the core area and outer limits discussed previously.

In 1951 the Dry Belt was considerably smaller than normal and was located much further to the north. The north, east and west boundaries of Köppen and Thornthwaite match surprisingly well and differences are to be noted in the Irrawaddy and Sittang Valleys where the Thornthwaite boundary extends less further south than does the Köppen boundary. Of particular note is the fact that in 1951 Pagan and Pakokku, at the traditional core of the Dry Belt, both lie outside of Thornthwaite's dry boundary. Note also the fact that Thornthwaite isolates five stations along the Mandalay-Kyaukse axis to form an island of humid climate surrounded by semi-arid conditions. This pattern is not revealed by Köppen.

In 1957 the Köppen boundary enclosed almost its normal total area and approximated its usual shape. It was, however, located south of its normal position and included Thayetmyo in the Irrawaddy Valley and Yamethin in the Sittang Valley.

This same year Thornthwaite's semi-arid area was about 400 percent of its normal size and extended far to the north and south of its normal location.

As was the case in 1951, Köppen limits extended south of Thornthwaite's in the Irrawaddy and Sittang Valleys. Köppen also included considerable sections of the Lower Chindwin Valley not included within Thornthwaite's semi-arid boundary. A particularly interesting feature of this map is the extension of the Thornthwaite boundary considerably beyond the Köppen boundary in the Shwebo District between the Irrawaddy and the *Mu* Rivers. This extension of the Thornthwaite boundary beyond the Köppen boundary is apparently due to the fact of a very dry early and middle rainy season followed by almost nine inches of rainfall in October. This was enough precipitation to classify Shwebo and surrounding areas as Aw according to the Köppen system and thus exclude the region from the Dry Belt for the year 1957. In this example the very heavy late season rains did not compensate for the long dry and hot mid season according to the Thornthwaite formula, and Shwebo was included within the Dry Belt. Thus the more complex Thornthwaite system is shown to be more sensitive to seasonal characteristics and less strongly influenced by short term patterns than is the Köppen system.

Maps 38 and 39 for 1953 and 1954 show rather close correspondence between the two systems with the Thornthwaite boundary enclosing a somewhat smaller area than the Köppen, as is to be expected. In 1954 an island of humid climate shows up in the central portion of the Chindwin Valley on both systems. This resulted from very heavy August, September and October rainfall recorded at several stations in the Lower Chindwin District. In this case the three month period of above average precipitation more than compensated for below average early summer rainfall.

THE WATER BALANCE

Precipitation and temperature are perhaps the most important of the climate elements in terms of man's use of an area. Location at a typhoon-prone site or in a section subject to frequent tornadoes has induced man to modify somewhat his use of certain areas, but such is not the case in Burma. Wind as a climate element by itself has little impact on life in Burma. Atmospheric pressure, the fourth weather element, also appears to be of little consequence to the people of Burma except in that pressure differences cause the development of air flows which in turn may bring precipitation.

Precipitation and temperature alone, however, do not add up to equal the real climate of any part of the world. Perhaps in Burma, a country of the "wet monsoon tropics", bare data on rainfall and temperature is even less useful than it would be for midlatitude countries. In Burma, with its pronounced rainfall rhythm, periods of massive water surpluses alternate with periods of serious and prolonged drought.

For a more accurate picture of the volume of surplus above need and of the seriousness of the drought period, a series of six water balance charts have been constructed. [1]

The stations for a study of the water balance were chosen on the basis of geographical distribution and completeness of available data. Akyab represents the wettest and the most pronounced of the monsoon areas, Rangoon is typical of conditions in the vast Irrawaddy Delta, Mandalay and Minbu are representative of Dry Belt conditions, Toungoo is midway between the heart of the Delta and the core of the Dry Belt, while Taunggyi demonstrates conditions on the important Shan Upland.

On these charts the normal precipitation, the potential evapotranspiration and the actual evapotranspiration are plotted by months and connected by lines. In months where the rainfall is greater than the actual evapotranspiration the rain that falls either soaks into the soil and is held as soil moisture or it runs off as surface or underground drainage. In the case of Akyab "normal" data shows that the first 6.89 inches of rain to fall after precipitation exceeds actual evapotranspiration (mid-April) is absorbed by the soil and is called soil moisture recharge. From that time on until approximately November 10 precipitation exceeds actual evapotranspiration and the difference between the two represents water surplus or runoff. During this season Akyab enjoys a surplus of 151.72 inches of rainfall.

Once rainfall drops below potential evapotranspiration, moisture is drawn from the soil. Under these conditions actual evapotranspiration is always less than potential evapotranspiration because moisture is released from the soil gradually and moves either through the plants to be transpired or by capillary action toward the soil surface to be evaporated only slowly. During such periods moisture which had been stored in the soil is released and is shown on the charts by horizontal lines. Immediately following a period of water surplus the volume of soil moisture is high and actual evapotranspiration is only slightly lower than potential evapotranspiration, as may be seen by the December conditions at Akyab. The difference between the potential evapotranspiration and the actual evapotranspiration represents the water deficit for the month and is shown with the heavy dot pattern.

As the dry season extends over longer and longer periods the volume of moisture stored in the soil and thus available for evapotranspiration becomes less; actual evapotranspiration falls further and further below potential evapotranspiration and the water deficit becomes larger. This is illustrated for the months of February, March and April at Akyab. Here the total soil moisture utilization for the normal year is 6.89 inches (identical to the soil moisture recharge at the beginning of the wet season) and the dry season water deficit equals 8.89 inches.

Mandalay provides a very interesting example of conditions in the Dry Belt where a water deficit exists throughout the year. At no month in a normal year does precipitation equal the potential evapotranspiration. Here the plants are not able to make use of any significant volume of moisture stored in the soil from

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1 For a detailed discussion of the method used see: Thornthwaite, C. W. and J. R. Mather, "The Water Balance", **Publications in Climatology**, Drexel Institute of Technology, Laboratory of Climatology, Vol VII, no. 1, 1955. See also by the same authors in the same series: "Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance", Vol. X, no. 3, 1957

a wetter period and must rely totally upon the precipitation that actually falls. Much of this moisture is absorbed by the upper layers of the soil and is evaporated rapidly from the surface or transpired by the plants. Precipitation makes no significant contribution to soil moisture storage in any month during a normal year and a moisture deficiency is the rule. Actual water deficit totals 30.73 inches annually with April, March and July, in that order, being the months of most serious drought.

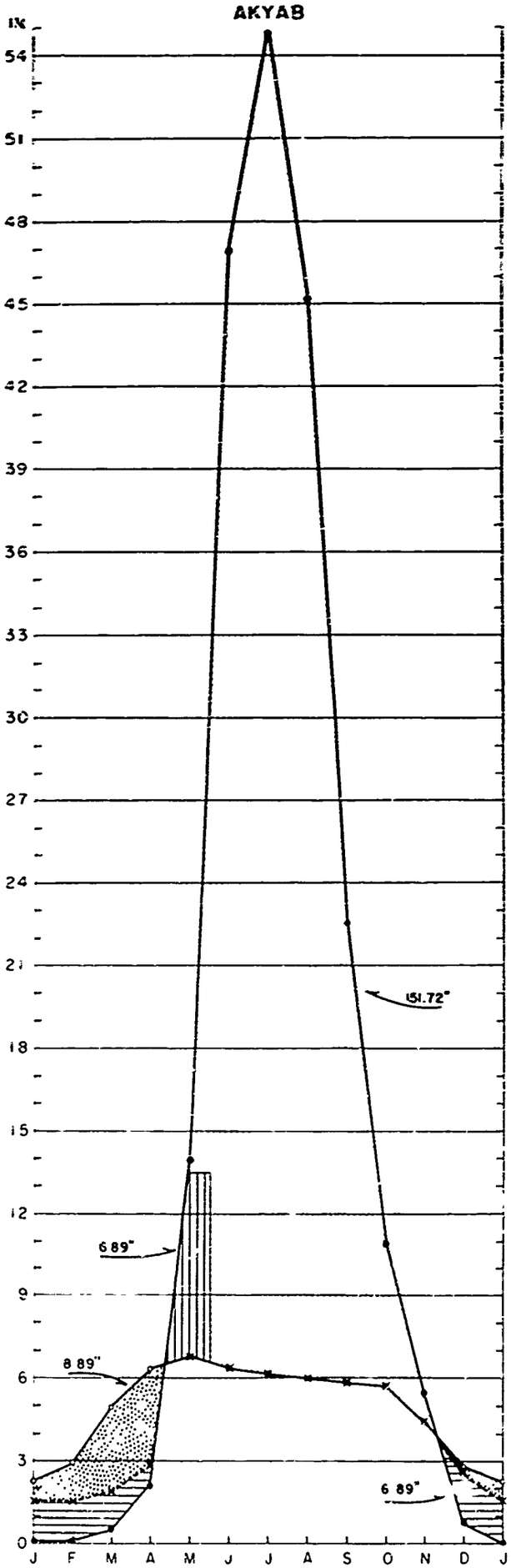
Clearly the capacity of the soil to retain moisture is a function of the type of soil involved and the character of the vegetation. A fine sandy soil is not able to hold as much moisture as is a heavy clay soil.

By the same token it is also clear that crops such as spinach, beans, beets and lettuce, being very shallow rooted, are able to utilize moisture from only a thin layer of surface soil while a closed mature forest has a root system extending many feet below the surface and is able to utilize soil moisture to a considerable depth. For purposes of the water balance charts presented here, soil and crop type were assumed to be similar at all stations. The soil is of a clay loam variety found throughout Burma and the crops were limited to moderately deep-rooted types such as rice, millet, cotton and tobacco.

Root penetration depends not only on the crop but also on the type of soil. Thornthwaite and Mather indicate that for the soil and vegetation types postulated above the root zone extends approximately 2.67 feet below the surface. This was the figure utilized in the construction of the charts.

WATER BALANCE

GRAPH 14



Precipitation

Potential Evapotranspiration

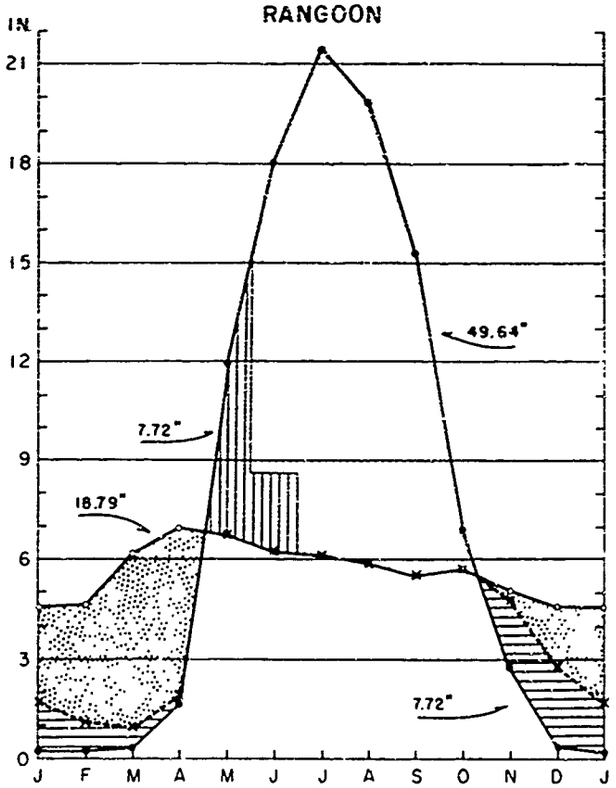
Actual Evapotranspiration

Water Surplus

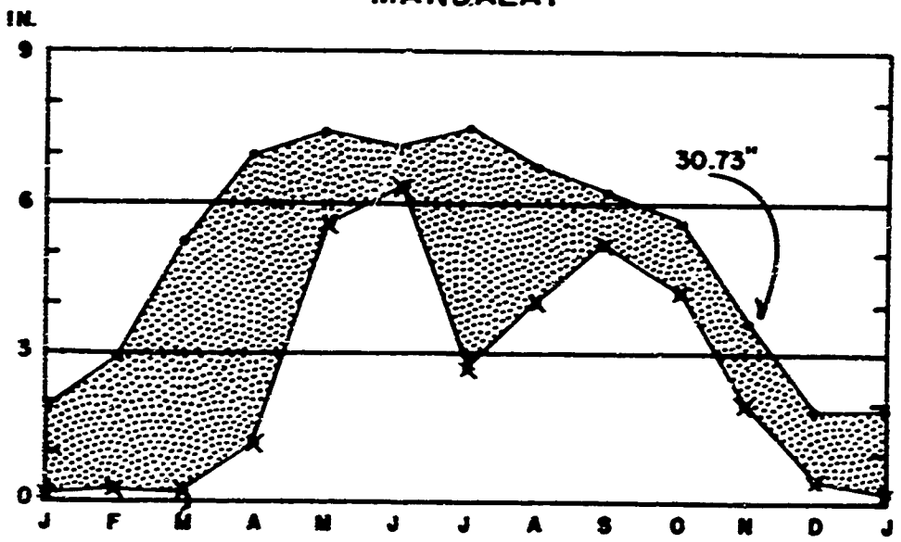
Water Deficit

Soil Moisture Utilization

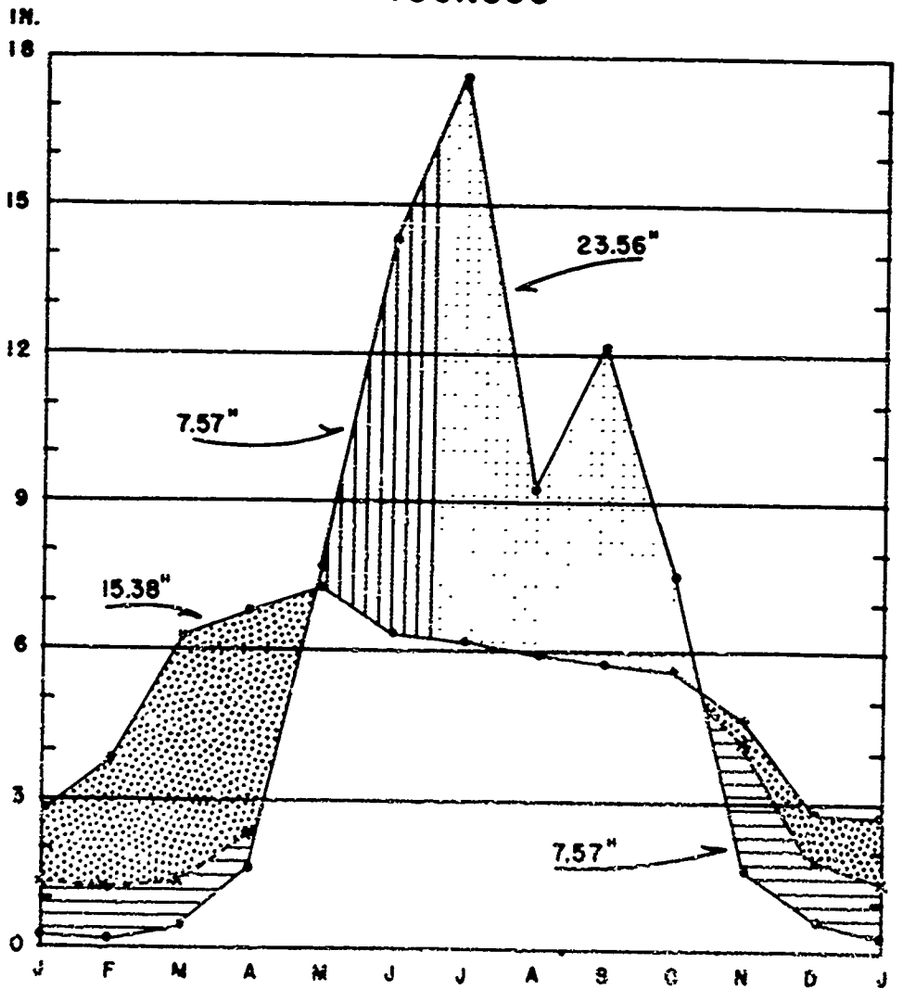
Soil Moisture Recharge



MANDALAY

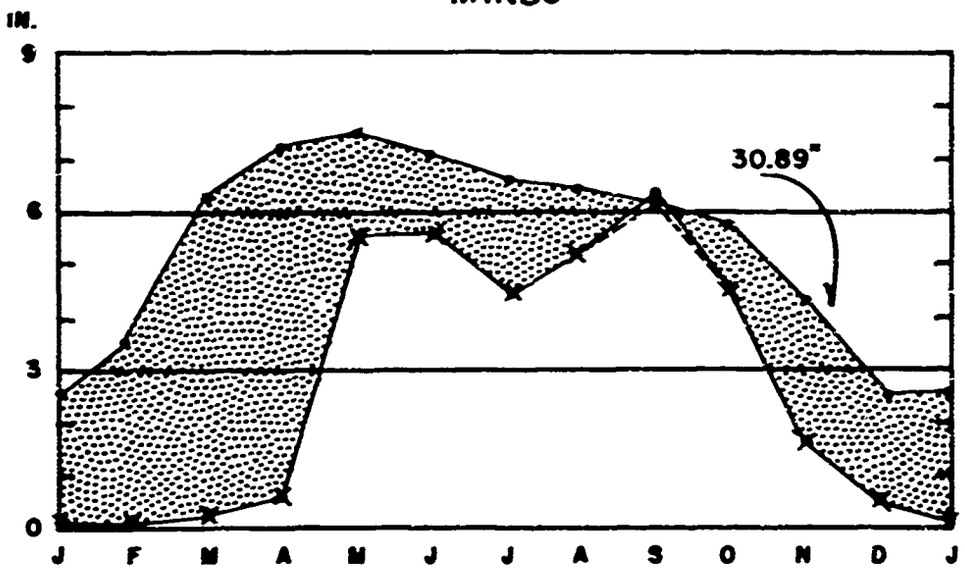


TOUNGOO

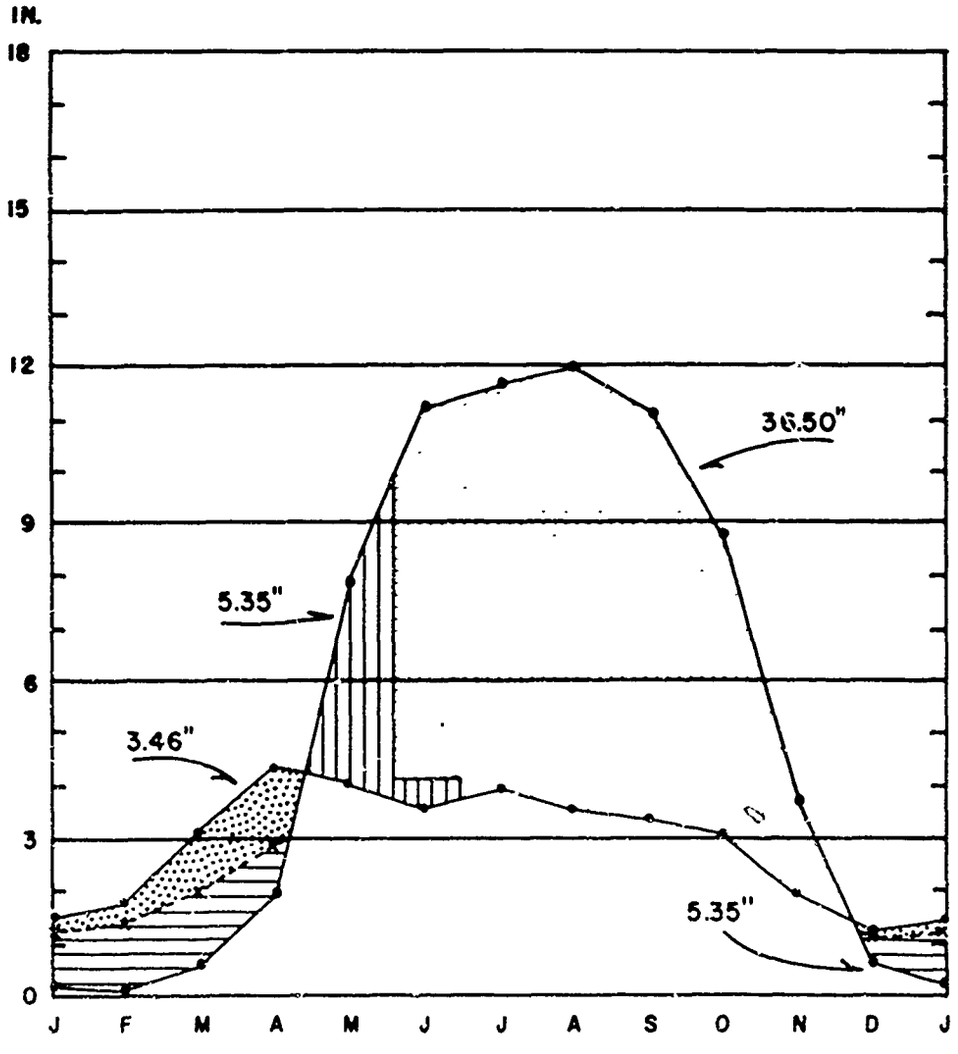


GRAPH 15

MINBU

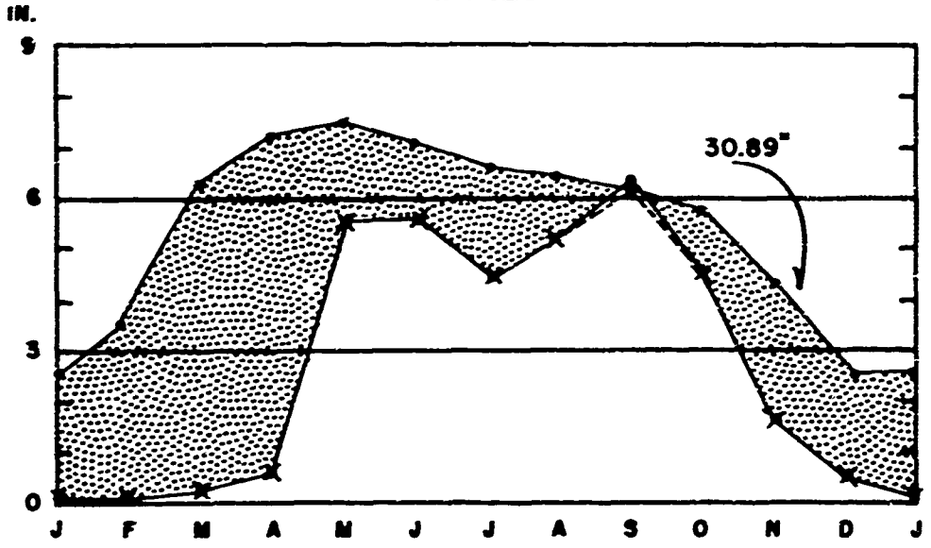


TAUNGGYI

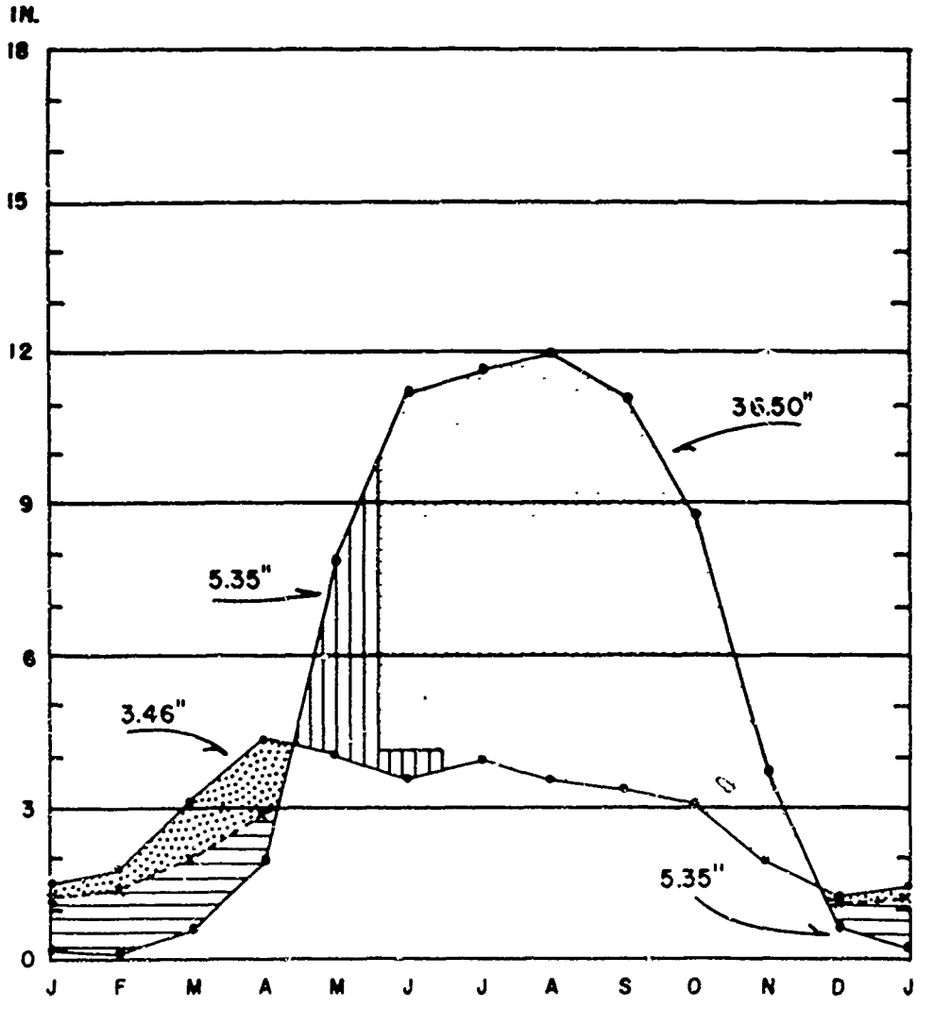


GRAPH 16

MINBU



TAUNGGYI



GRAPH 16